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ARC WELDING

THE NEW AGE IN
IRON AND STEEL

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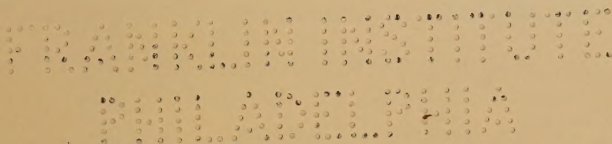
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ARC WELDING

The New Age
in
Iron and Steel



Price \$1.50

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Table of Contents

Chapter	Page
I. The New Age of Steel.....	3
Addenda. Steel Versus Cast Iron.....	23
II. Arc Welding Makes Riveting Obsolete.....	31
III. What Arc Welding is and What it Does.....	45
Addenda. Other Methods of Welding.....	55
IV. Arc Welding in General Manufacturing.....	57
V. Strength of Arc Welded Joints.....	111
VI. The Speed and Cost of Welding.....	123
VII. Automatic Arc Welding.....	135
Advertising Section.....	147

Instructions . . . Supplement in back

CHAPTER I

The New Age in Iron and Steel

DURING the first quarter of the twentieth century we have entered a new age in the use of iron and steel.

It is an age in which all things fashioned from iron and steel will be finer, stronger and better, yet they will be produced for a fraction of their former cost.

It is an age in which the established methods and traditions of metal working will be cast ruthlessly aside. Sweeping changes in designs and processes will be the inevitable result in every plant where iron and steel is used as raw material.

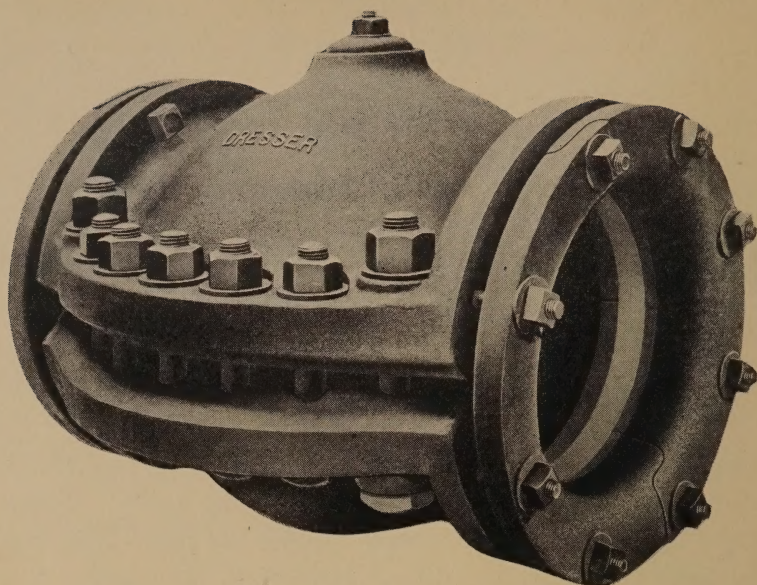
These basic changes in the world's greatest industry are even now resulting from the use of electric arc welding.

This statement is made in full knowledge that it will be challenged by men who have spent their lives in working these great metals.

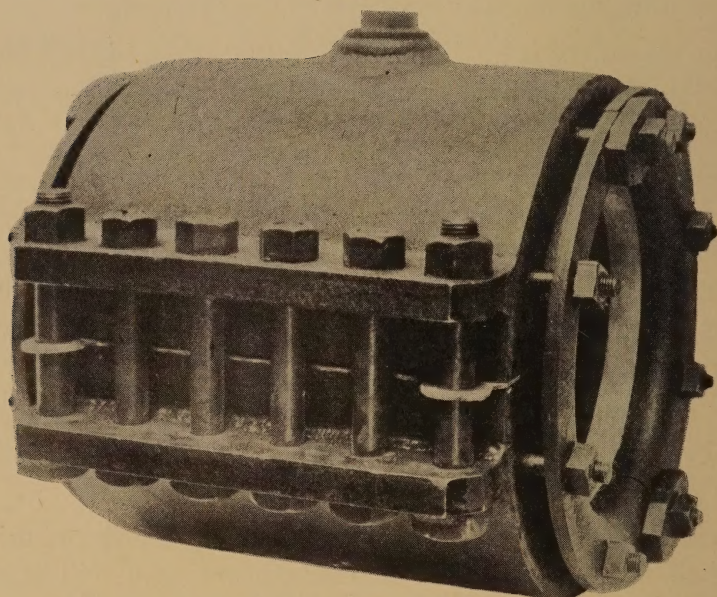
It is a matter of history that those who will be most affected by any great change are the last to see it coming. The sailing masters were among those who scoffed most at Fulton's new steamboat, and no one laughed so long or loudly as did the buggy maker when Henry Ford brought out his first horseless carriage.

By the same token America's greatest fortunes have been built by the few men who could see such new developments and sense their significance before their fellows.

Electric arc welding offers just as certain an opportunity for profit to those far-sighted manufacturers who will study its possibilities with an open mind and a firm determination to apply it to their own products.



CAST IRON, 908 POUNDS
Fig. 1



ARC WELDED STEEL, 395 POUNDS
Fig. 2

S. R. Dresser Manufacturing Co., Bradford, Pa., save over half the weight by making this split sleeve of arc welded steel instead of cast iron. These split sleeves are used in the oil fields and freight is a big item on many of their products. Arc welding cuts the freight bill in half. The manufacturing cost is also greatly reduced and the product is more reliable.

Statement of Advantages and Method of Proving the Victory of Steel Over Cast Iron

Cast iron as a material for manufacturing machinery is much inferior to steel in all ways—in fact, steel makes the present industrial age possible. There is practically no mechanical advance now existing which would be possible if the cast form were the only one that iron can take. The railroad, steamboat, automobile, telephone, radio, and airplane are all impossible in the light of cast iron only. Civilization would go back to the dark ages without steel, yet all things now made from cast iron can be equally well produced from steel.

We are dealing, however, with a world where both cast iron and steel may be used by the designer and this book has to do with the economics of the question only.

Rolled steel for machine manufacturing has four fundamental advantages:

1. Steel costs one-third as much per pound as cast iron.
2. Steel is approximately six times as strong in tension as cast iron (working strength).
3. Steel is two and one-half times as stiff as cast iron.
4. Steel is more uniform. Therefore, a smaller factor of safety can be and is always used for equal

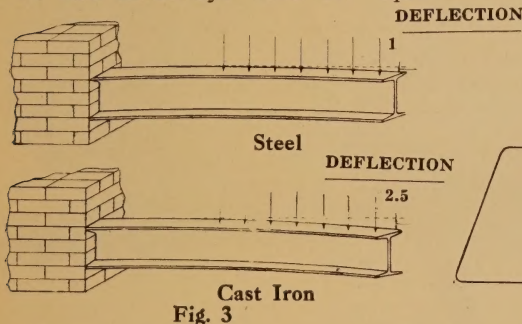


Fig. 3

Steel is two and one-half times as stiff as cast iron.

safety than for cast iron.

There are other advantages of great importance from a cost saving standpoint which are discussed, but the above four reasons are the fundamentals.

Cast iron has been used heretofore because it is easy to cast into any shape, hence its fundamental unsuitability to the purpose has been overlooked, but the arc welder has made it possible to form standard steel shapes into practically any form and the last reason for its continued use has disappeared. When it is remembered that steel also is a much more suitable and less costly material, the rapid change from cast

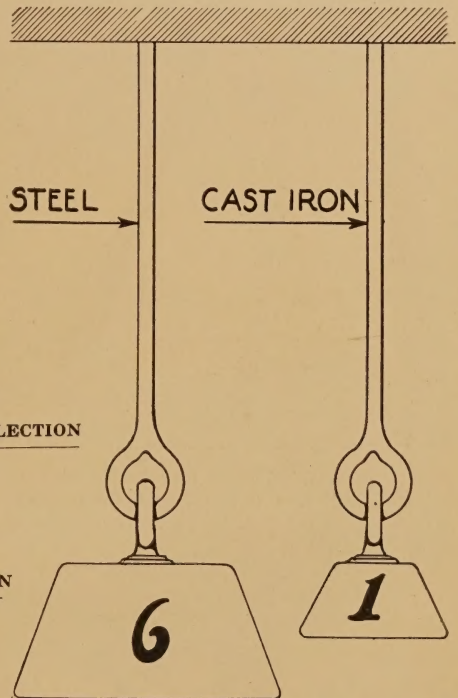
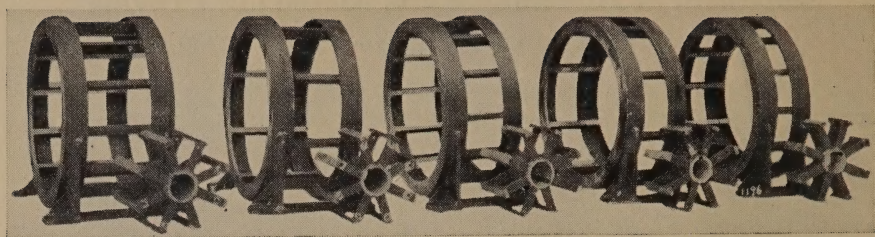


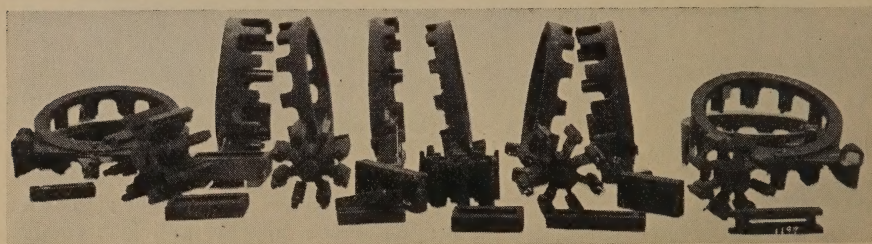
Fig. 4

Steel is six and one-half times as strong as cast iron in tension.

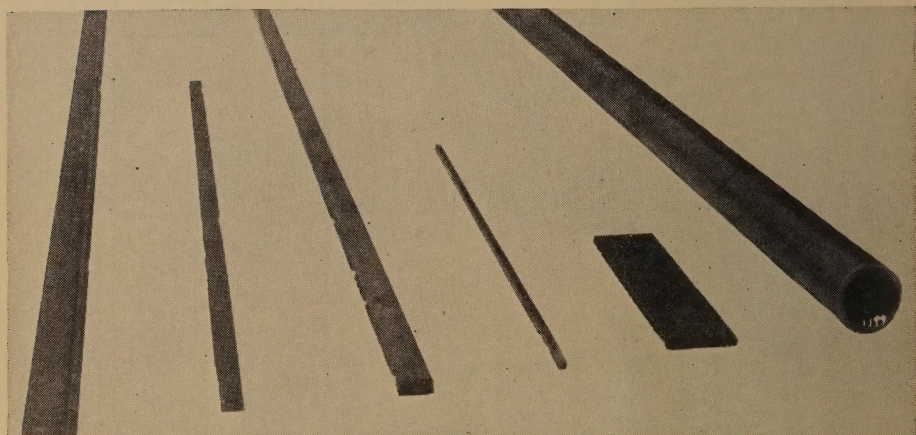
NOTE—A complete semi-technical discussion of the relative strength and economy of steel as compared with cast iron will be found at the end of this chapter on pages 23 to 29.



To make these five motor frames and rotor spiders of cast iron.



All of these patterns and core boxes are required.



Where arc-welded steel is substituted for cast iron, no patterns or core boxes are needed. All five motor frames and rotor spiders are made from the six standard steel shapes illustrated.

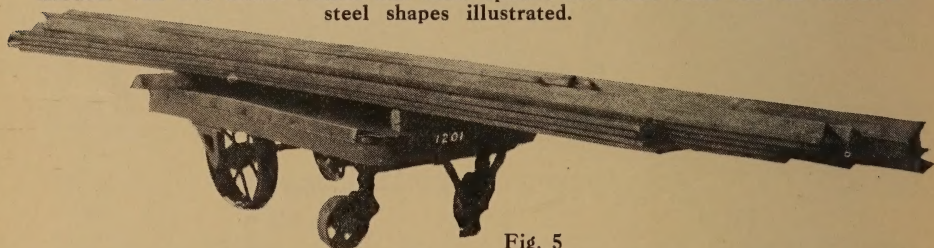


Fig. 5

This means that a much smaller material inventory is required because the steel jobber carries all of these shapes in stock. Furthermore much less storage space is required. The illustration shows all material for the five motor frames and rotor spiders loaded on one shop truck. The total manufacturing cost is cut in half.

iron is assured.

Other advantages which naturally flow from the substitution of steel for cast iron are:

- a. Cutting cost of development of new design.
- b. Elimination of pattern expense.
- c. Elimination of obsolete parts.
- d. Reducing of cost and amount of necessary machining.
- e. Reducing of building space for the same output.

- f. Reducing of the raw material inventory and the total material cost.

The sum of all these savings will average at least one-third of the cost of any product now made from castings if it is large enough so that structural steel can be applied to it, and many cases have come to the writer's notice where savings much in excess of sixty percent have been made by the substitution.

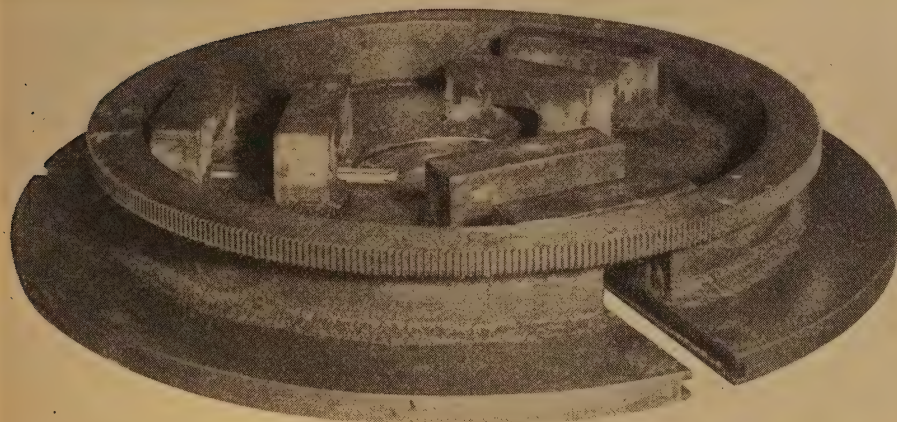
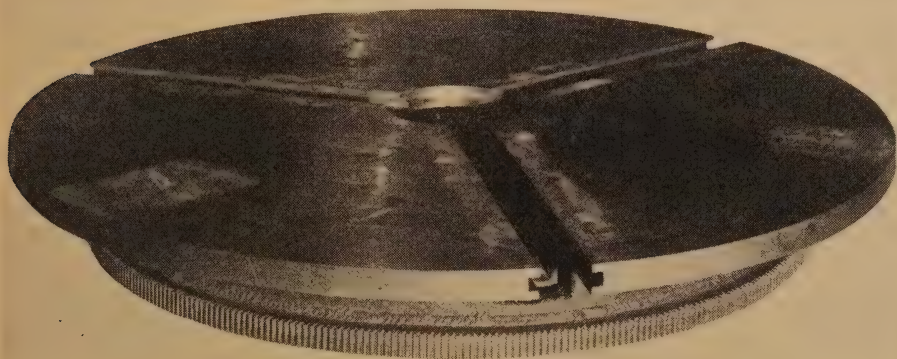


Fig. 6

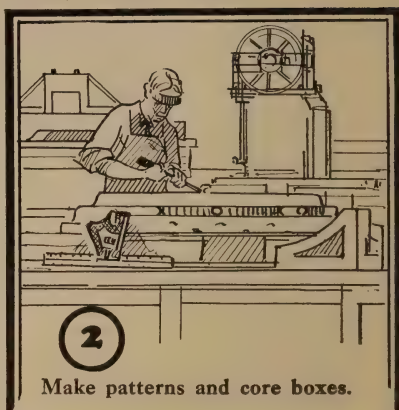
ROTATING TABLE

A little ingenuity plus an arc-welder make it possible to substitute arc-welded steel for almost any casting at a distinct saving in cost. Here is a rotating table made of standard steel shapes.

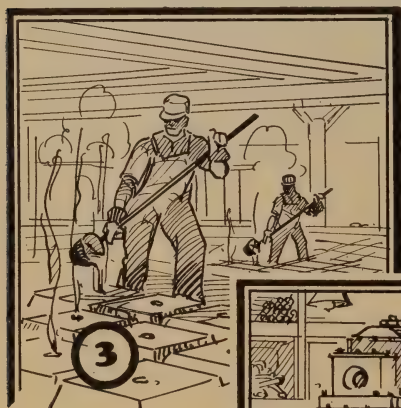
THE DEVELOPMENT OF AN IDEA IN CAST IRON



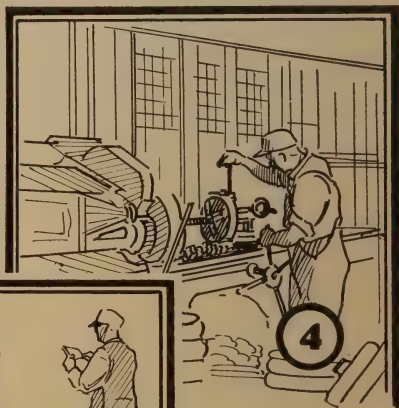
1 Make detailed drawings.



2 Make patterns and core boxes.



3 Make mold and pour casting.



4 Machine rough castings.



5 Assemble complete product.

THE DEVELOPMENT OF AN IDEA IN ARC-WELDED STEEL

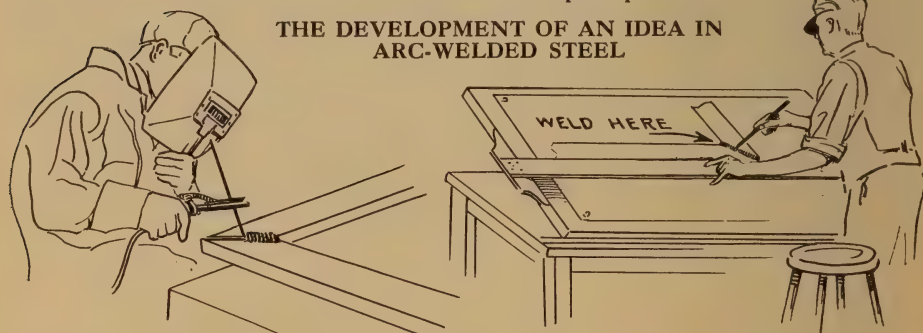


Fig. 7

The welder works direct from rough sketches, often eliminating all machine work and always reducing the time and cost of assembly.

Cutting Cost of Developing New Designs

. How large the item of "Development Work" looms in many an operating statement! How many firms could show a substantial profit if this item could be cut down in their annual budget!

Consider, for instance, the development of an idea in cast iron:

A manufacturer desires to develop new models. Days are spent on the drafting board—days are spent in the pattern shop—more days in the foundry—and when thousands of dollars in time and money have been invested the first model is ready for test. Too often

the tests are unsatisfactory and the whole costly process must be repeated.

Contrast such a proceeding with that where arc welding is intelligently employed.

Rough sketches can go direct from engineering to welding shop. Patterns are unnecessary. Actual working models can often be brought together in a few days' time.

Think of the saving in investment and the saving in valuable time in putting a new design on the market!

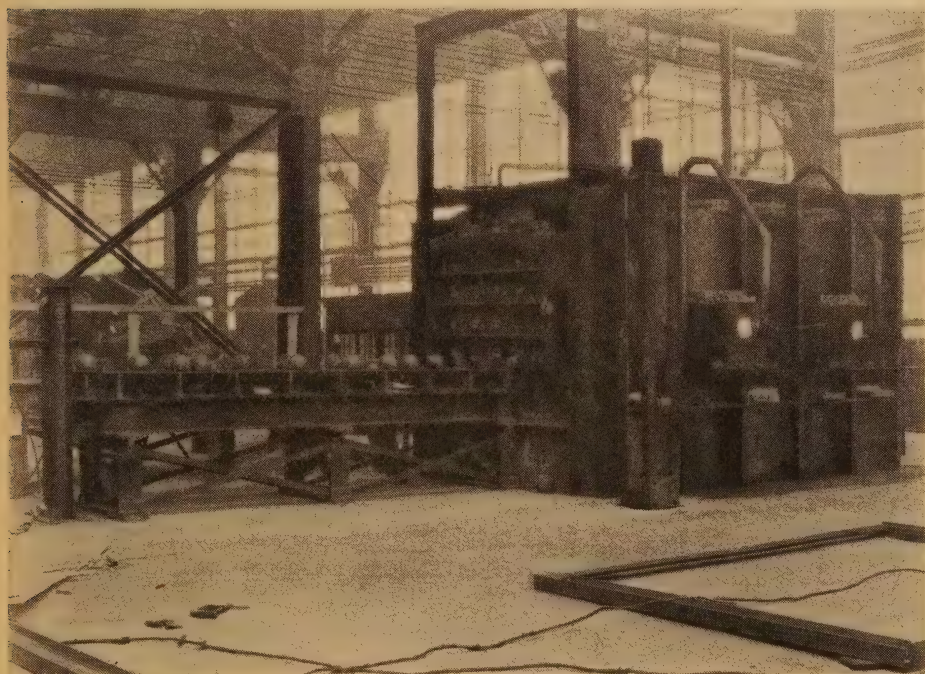
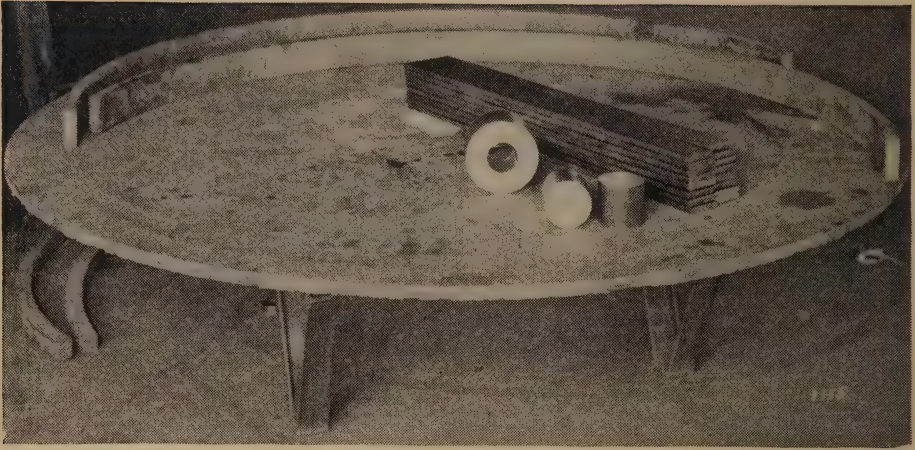


Fig. 8

This annealing oven was built complete by arc welding. No detailed drawings were made. Forty-nine hours after rough sketches were given to the welding foreman the oven was ready for the brickwork. This oven is one of four recently built by The Morgan Engineering Company.



These plates and bars welded into a single piece make up the top of the turntable shown below.

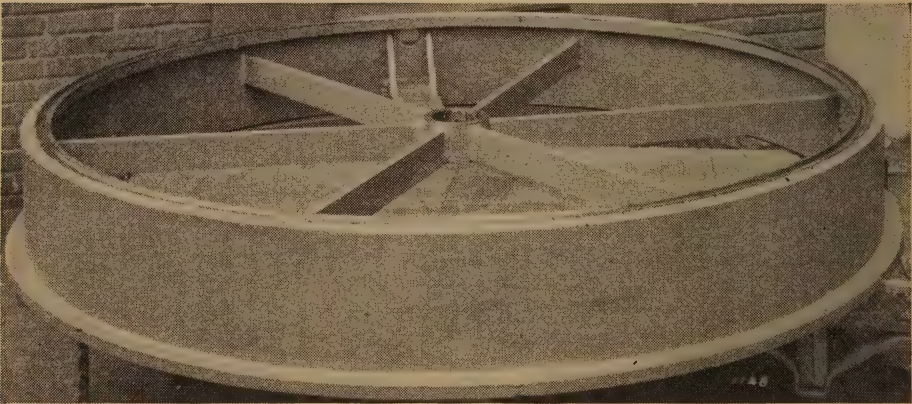
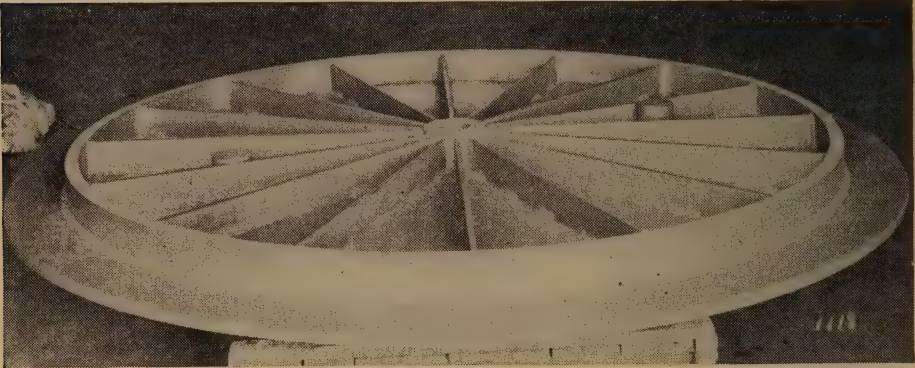


Fig. 9

TURNTABLE FOR AUTOMATIC MACHINE

There is no pattern expense to be charged against this job. The base and turntable are made of standard bars and plates, arc-welded for strength and economy.



Fig. 10

The pattern storage of a well known manufacturer before adopting arc welding.

Elimination of Pattern Expense

Nor does the saving stop here. The interest on the investment in patterns, the expense of their storage, repair and insurance are items which can be largely eliminated where the product is welded in steel.

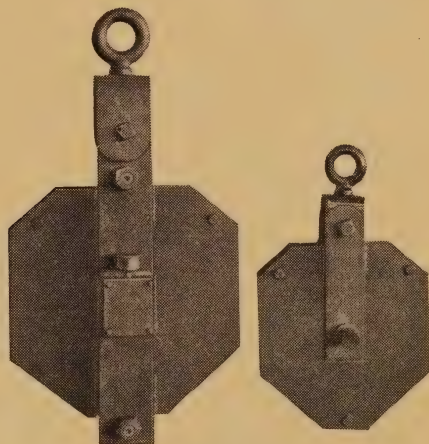


Fig. 11

Why use castings for sheave blocks requiring a separate pattern for every size and style? Arc-welded steel is stronger, lighter and cheaper. Any size or style can be made from standard steel shapes.

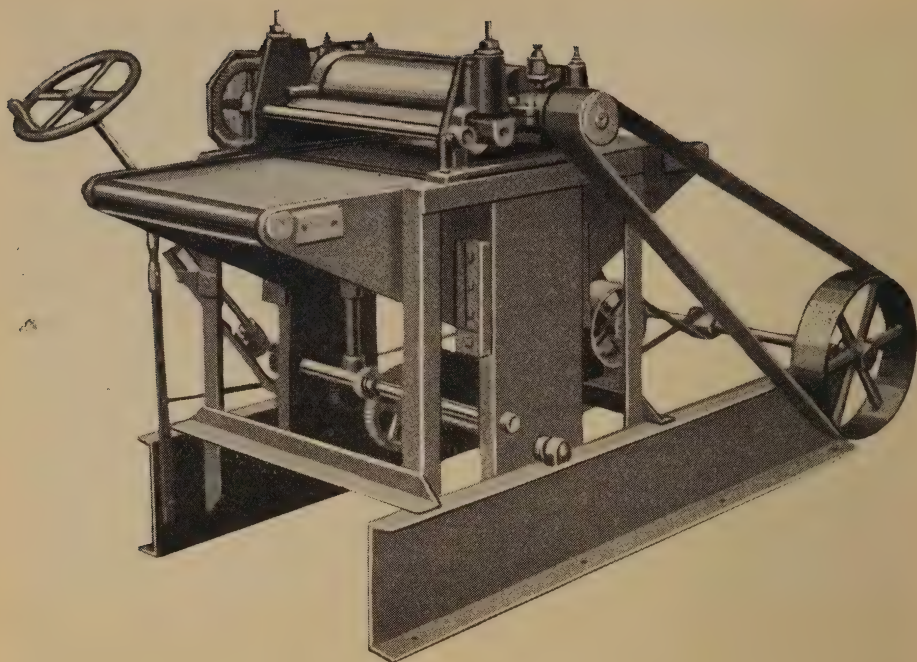


Fig. 12

Arc-welded steel will supersede cast iron for making bases for machinery of all kinds. Since steel is twice as rigid as cast iron the saving in weight is apparent. Illustration by the courtesy of The Parks Ball Bearing Machine Co., Cincinnati, O.

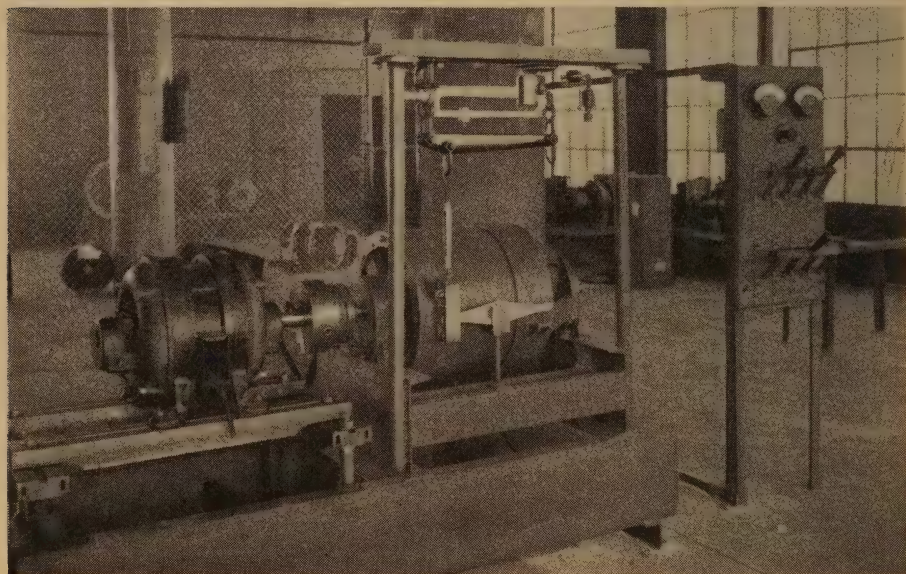


Fig. 13

The base of this dynamometer is extremely rigid. It was also cheaper to build than a cast-iron base.

Lower Material Inventory

The manufacturer who uses cast iron must in self protection carry a heavy inventory of all the different castings which may be called for on any of his models or designs.

Very often this item is equivalent to a large percentage of his capital investment. It is an item which he must frequently borrow money to cover while the parts lie idle and profitless in his storage.

By contrast the manufacturer who builds his product from steel needs only a small stock of the different standard steel shapes he uses from which his welding de-

partment can fabricate in a few days the necessary supply for any order.

This is because any one of a large number of different parts can be made up of standard steel shapes of the same size and style whereas a casting can seldom be used for any purpose other than the one for which it was designed.

In actual practice one manufacturer of a large line finds that his inventory of steel is less than eleven percent of the amount he used to carry tied up in iron castings.



Fig. 14

This small stock of standard steel shapes replaces a casting storage covering about one-half acre.

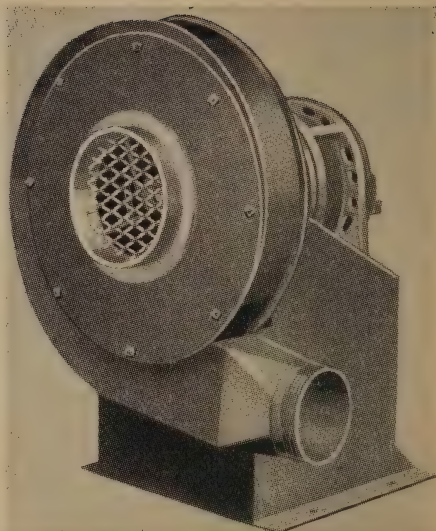
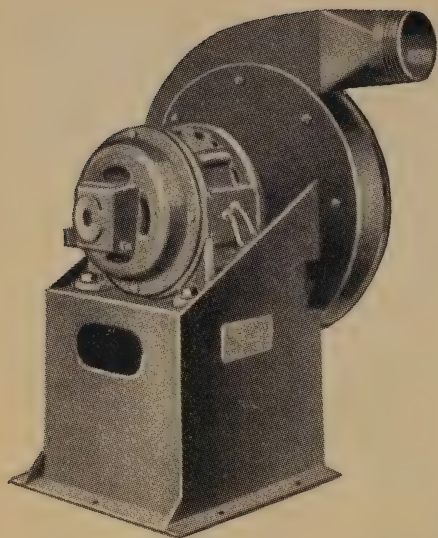


Fig. 15

Arc-welded steel replaced cast iron in the manufacture of this turbine pressure blower manufactured by the Robinson Ventilating Co., Pittsburgh, Pa. The welded steel base is lighter, stiffer and cheaper to build.

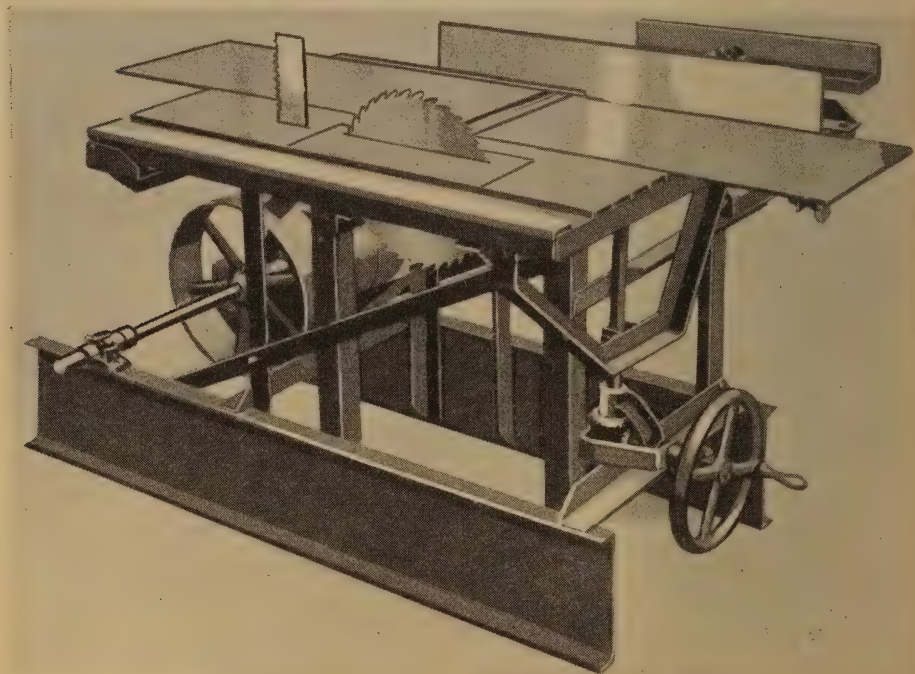


Fig. 16

This combination circular rip and cross cut saw, 12 inch joiner and boring machine is supported by a frame of arc-welded steel. Strength, lightness and economy are the results. This is only one of the uses that the Parks Ball Bearing Machine Co., Cincinnati, Ohio, makes of arc welding.

No Obsolete Parts

The organization has not yet been found that can estimate exactly the number of any given model that will be built nor even the number of parts of each kind that are needed for a given production.

Finally with the best of estimates, breakage and mis-machining are to be reckoned with. And so it

comes about that with the discontinuance of certain designs there are left many hundreds of obsolete castings which at best can be inventoried only at scrap value.

This annual waste has been almost entirely eliminated in plants where welding is used to the fullest extent.

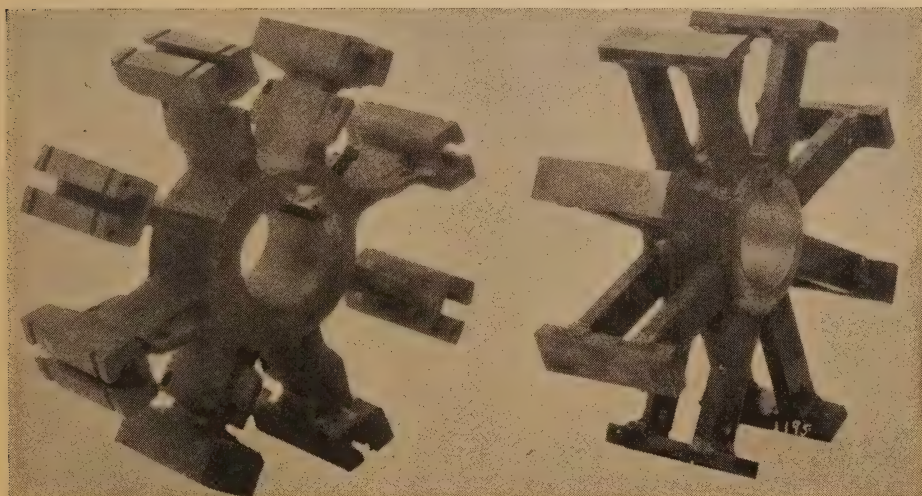


Fig. 17

ROTOR SPIDER FOR ELECTRIC MOTOR

Cast Iron, Wt. 70¼ Lbs.		Arc-Welded Steel, Wt. 43¼ Lbs.	
Cost of rough casting	\$6.75	Cost of rolled steel	\$1.28
Labor cost	2.94	Labor cost	4.37
Total cost	\$9.69	Total cost	\$5.65

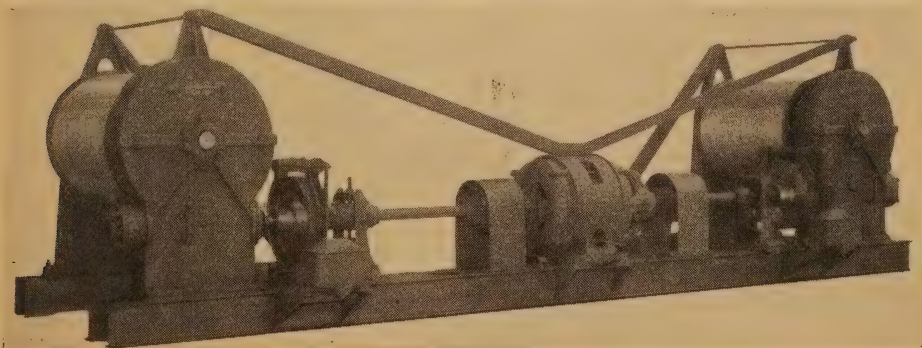


Fig. 18

Double elevator machine for use in a paper mill. The base of this machine is 19 feet long and is built of standard shapes joined by arc-welding.



Fig. 19

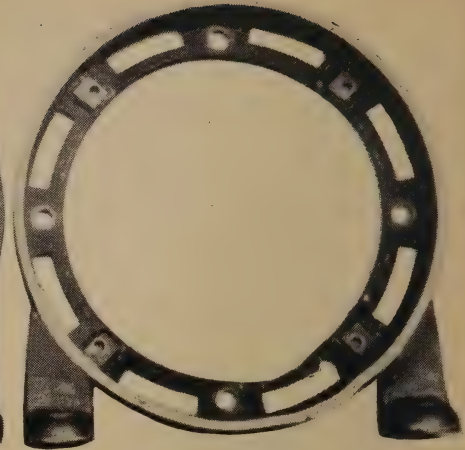


Fig. 20

END RING ON MOTOR

CAST IRON

Cost of rough casting-----	\$2.89
Labor cost -----	.195

ARC-WELDED STEEL

Cost of rolled steel-----	\$1.126
Labor cost -----	.407

Total cost ----- \$3.085

Total cost ----- \$1.533

Arc-welded construction costs less than one-half as much as cast iron.

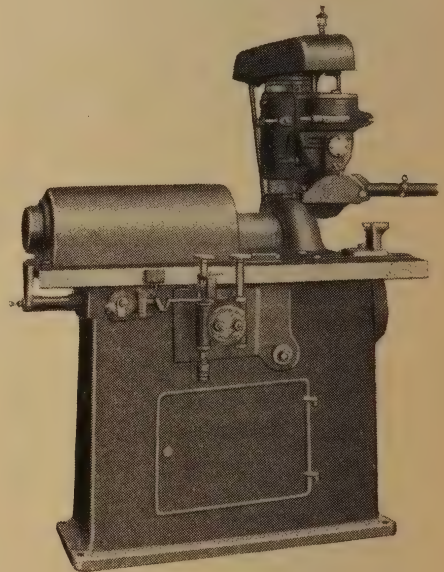
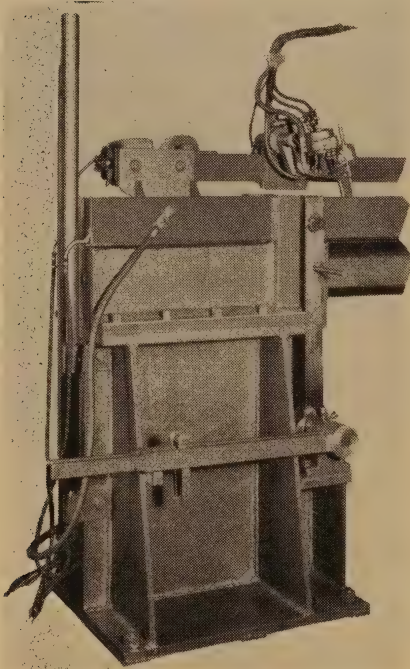


Fig. 21

Before arc welding was perfected machine bases were necessarily made by casting because there was no other method of getting the required rigidity. Now arc welded steel makes a more rigid base at a lower cost.

Little or No Machining

Last, but by no means least, is the cost of machining cast iron to finish surfaces or for the necessary fit. This cost in large part is eliminated in welded steel where the surface is already hard finished by rolls and the sizes are so accurate as to demand no machine work.

When it is necessary to machine rolled steel the part can be finish machined without allowing weeks or months to elapse between the roughing and finishing cuts. There is no necessity for seasoning as there are no locked up strains in rolled steel such as are so objectionable in cast iron.

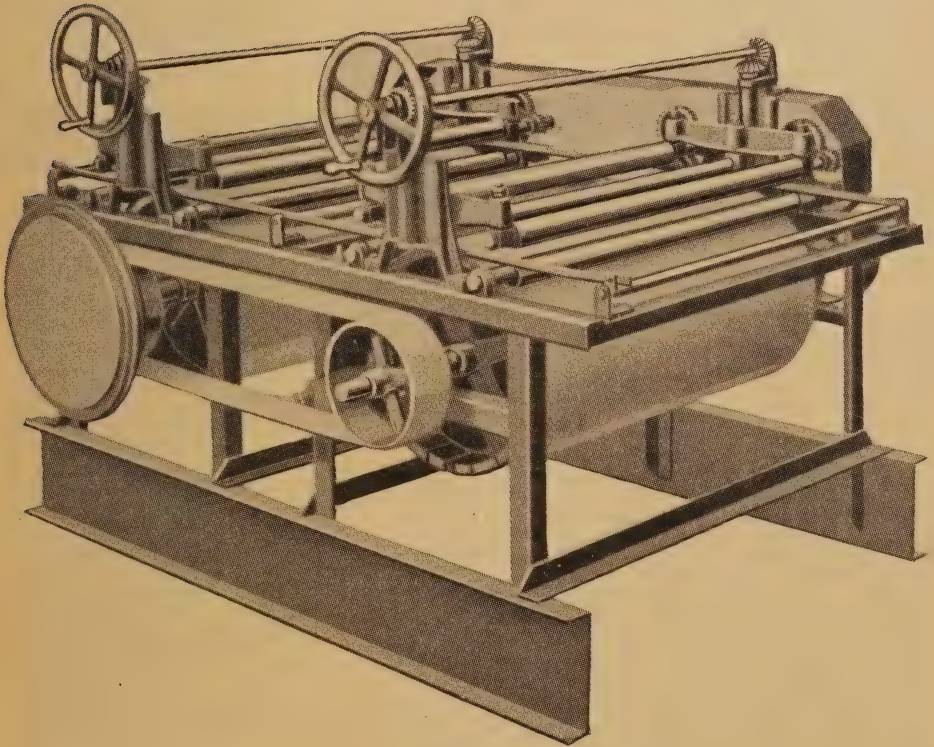


Fig. 22

Contrast the appearance of this rigid arc-welded steel base with the bulky, clumsy cast iron base generally used for machines of this nature. The arc-welded base is stronger and cheaper.



Fig. 23

Large foundry space required by manufacturer before adopting arc welding.



Fig. 24

The small welding shop required to make the same parts.

Less Building Space But Greater Production

What would it mean to the average manufacturer if he could increase his production 100% in important departments and at the same time cut in two his floor space?

Such radical savings are not theoretical possibilities, they are actually being made in plants where important parts of the product are now made by arc welding instead of by casting.

Take, for instance, the production of certain frames averaging 20 inches in diameter and 3 inches thick. These were formerly made in a foundry where a production of 60 per day required a molding floor space of 600 square feet to

say nothing of pig iron storage, tumbling barrel room, pattern storage, etc. Today that same frame is made by simply rolling a standard steel angle to circular shape and welding the ends.

The total floor space for the entire operation including storage of stock does not exceed 300 square feet.

The present cost of construction is such that no progressive executive is overlooking such an opportunity to make his present floor space more productive.

Here again is that inevitable economic force which is ushering in the new age in iron and steel.

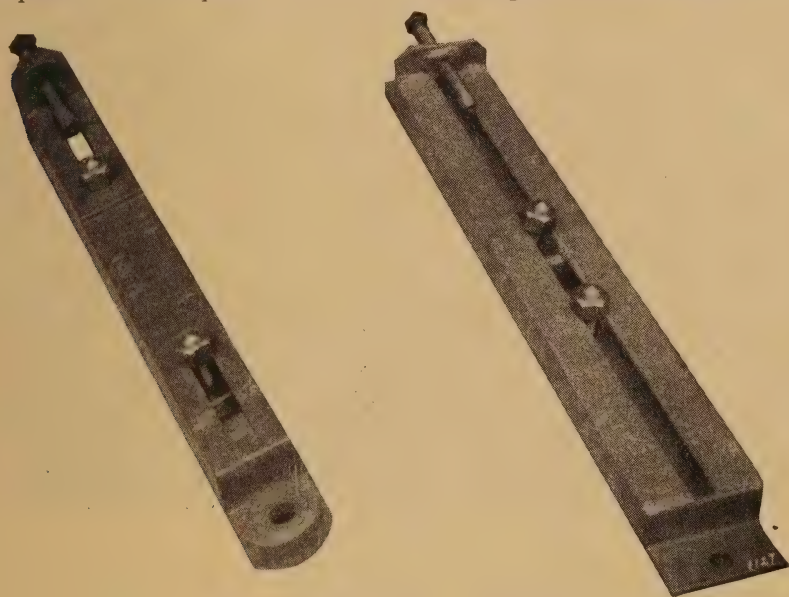


Fig. 25
MOTOR BASE RAILS

CAST IRON	
Cost of rough casting	\$4.992
Labor cost	.117
Total cost	\$5.109
Weight	77 lbs.

ARC-WELDED STEEL	
Cost of rolled steel	\$1.536
Labor cost	.617
Total cost	\$2.153
Weight	66 lbs.

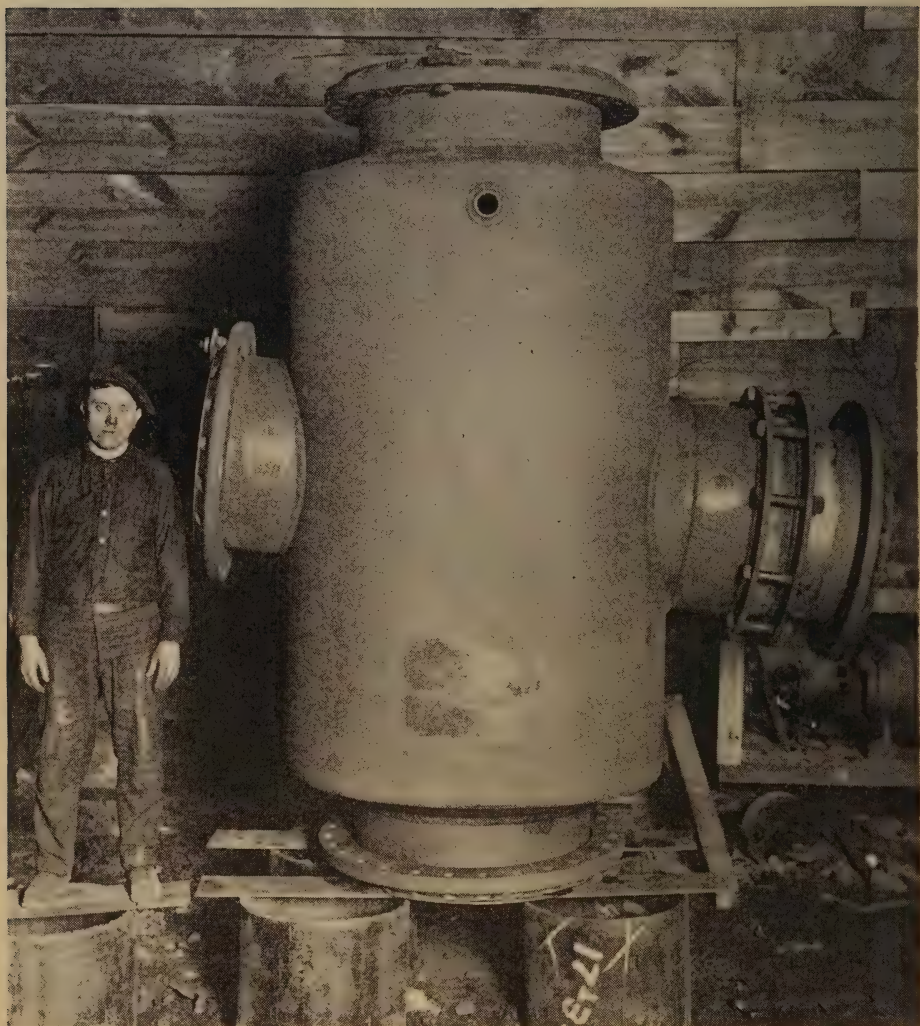


Fig. 26

The cost of making this huge manifold of cast iron would be enormous. By arc welding both the weight and cost are materially reduced. Oil refining equipment of every sort is now arc welded. Photograph by courtesy of the Power Piping Company, Pittsburgh, Pa.

Why is Cast Iron used when Steel is better and cheaper?

With all of the undeniable advantages which steel has over cast iron the question must arise as to why industry has not discarded cast iron entirely except for a few special applications. The only answer is tradition.

It is remarkable the extent to which tradition and custom rule our lives. The first railroad passenger cars were simply stage coaches on rails.

For many years the automobile was merely a glorified buggy instead of a new vehicle to be used under entirely new conditions.

It seems to be an unwritten law in designing any new product to make it look like the old rather than frankly to consider its purpose and then build it to suit that purpose.

Thus it has become tradition that a machinery base, for instance, must be a rectangular bulky piece of *cast iron* difficult to cast, needlessly heavy to ship, and unnecessarily high in cost.

We have a feeling that the sections of metal must be heavy and clumsy and that corners must be rounded—that supporting bases or pillars must taper from bottom to top.

All of this is nothing more nor less than tradition. For years we

have been used to the bulky shapes, heavy sections, rounded corners, and tapering members. Why? Because cast iron had to be bulky to get sufficient strength, and it had to be tapered and rounded in order to draw the pattern from the sand successfully.

Today with hundreds of examples in welded steel before us, there is no logical reason in the world for clinging to the old designs which were necessary owing to limitations of the casting process.

As an example of this consider a design in which it is desired to secure a very rigid pillar or base. The shape which will give the greatest possible rigidity or stiffness per pound of metal is the I-beam.

I-beams with the proper proportions to give maximum efficiency are stock items in rolled steel. It is not feasible, however, to make an I-beam of cast iron because of the impossibility of getting the proper proportion between the web and the flanges. Shrinkage and moulding difficulties practically debar the use of this most useful shape in cast iron.

There are thousands of cases like this where an inexpensive structure made from standard steel shapes is better in every way than the traditional cast iron.

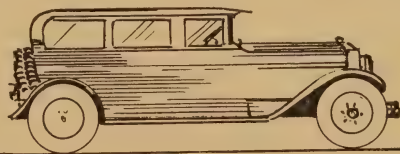
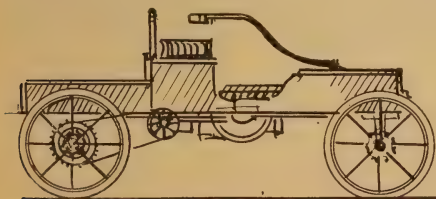


Fig. 27

Tradition was responsible for the looks of the early automobiles. They were made to look like buggies instead of being designed to meet entirely different conditions.

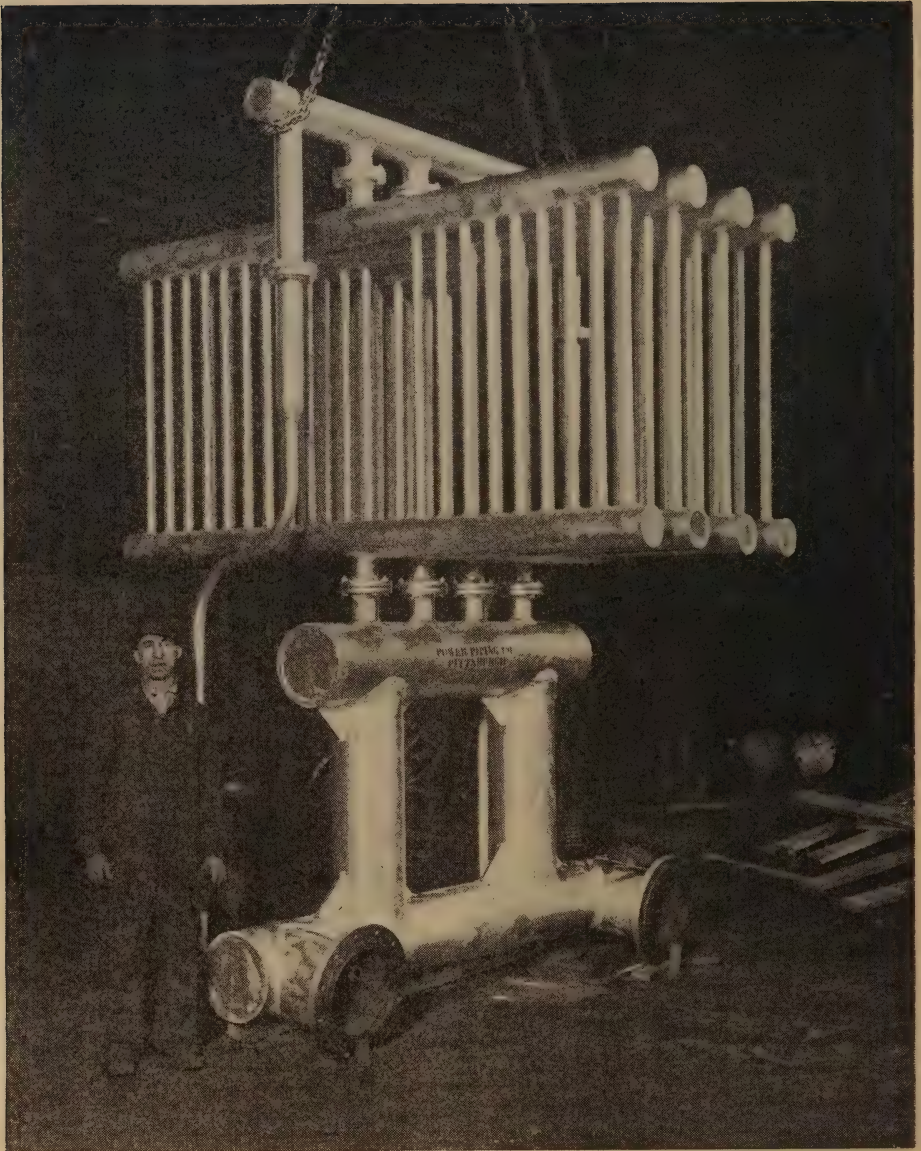


Fig. 28

Equipment for oil refineries is now built largely by arc welding. This condenser or harp is used to condense the hot gases as they come from the oil still, and has to withstand high pressure and heat. Arc welding reduces the cost of making this equipment to less than half of the cost of any other method. Note how this condenser is built up of standard sizes of pipe all welded together into integral parts. Built by the Power Piping Co., Pittsburgh, Pa.

ADDENDA TO CHAPTER I

Steel Versus Cast Iron—The Technical Facts

The use of cast iron is so general throughout all industry that at first glance one is apt to question the startling statements made in the foregoing chapter regarding the economy of substituting arc welded steel for cast iron. Any one who will follow the semi-technical discussion in the next few paragraphs cannot but be convinced that these statements are entirely correct and that in 90% of the places where cast iron is now used arc-welded steel would be better and cheaper.

material, unlike the carbon plates in cast iron, is stronger than the crystals themselves. This carbon-iron mixture forms a cement tougher than the aggregate or crystals of pure iron.

It is apparent from these photographs that steel is more uniform and homogeneous in structure than cast iron. Let us consider next the resistance which these two metals offer to various kinds of stress to which they are subjected in practice, namely, compression, tension and bending.



Fig. 29

Cast Iron.

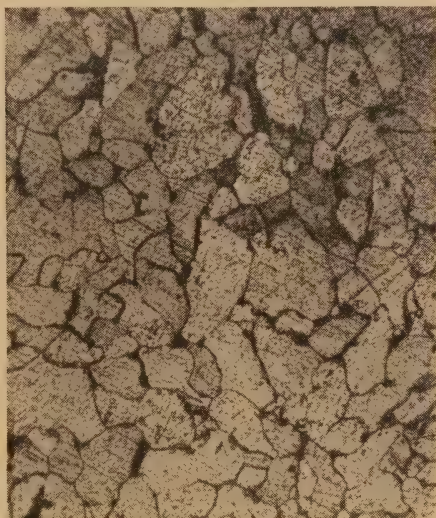


Fig. 30

Steel.

Microphotographs of cast iron and steel. Magnified 100 diameters.

The Structure of Cast Iron and Steel Compared

The two micrographs in figures 29 and 30 show the essential difference between cast iron and steel as regards structure. Both steel and iron contain carbon. The difference is that in cast iron the carbon is segregated into curved plate-like shapes distributed through the mass, while in steel the carbon is chemically combined with the iron. In cast iron these carbon spots are weak and break up the homogeneity of the metallic structure. As far as strength of the cast iron is concerned, these carbon plates might just as well be holes.

In steel, however, the carbon in combination is found in the boundaries of the metallic crystals. This boundary

Steel is Stronger Than Cast Iron in Compression

Tables of strength of materials give the compressive strength of cast iron as 90,000* lbs. per sq. in., and the compressive strength of steel as 55,000 lbs. per sq. in. This apparently indicates that cast iron is stronger than steel in compression. Let us examine the facts more closely. The figures given above do not represent the safe working limits but instead represent the ultimate or breaking stress. Naturally, in practice, metal is not stressed to the breaking point. The maximum allowable stress beyond which it is unsafe to go is found by dividing the ultimate strength by a number called the factor of safety. Sound engineering

*"Mechanical Engineers Handbook"—Marks.

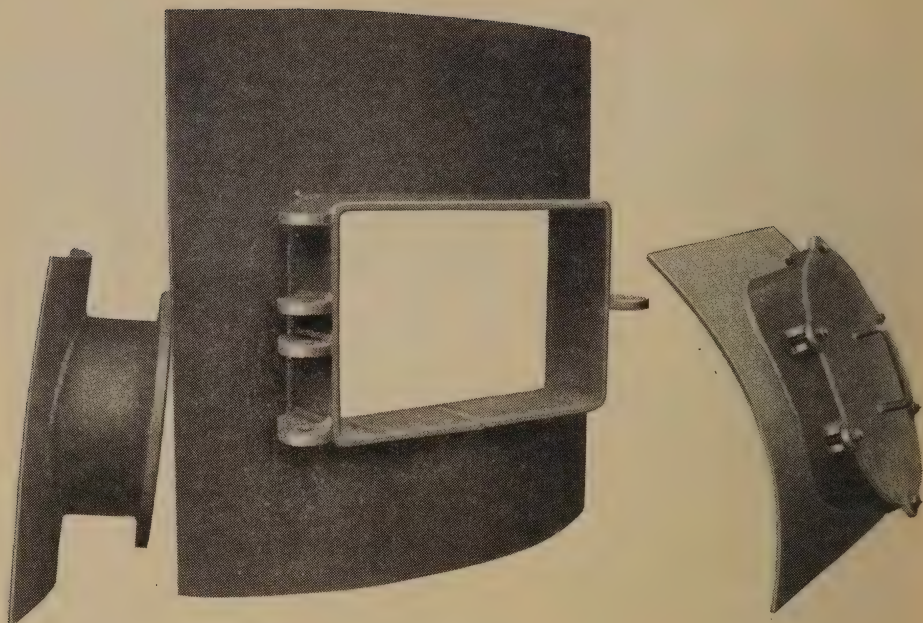


Fig. 31

These arc-welded door frames and manholes were formerly made of castings. Arc welded construction eliminates pattern expense which is a large item where only one or two similar parts are needed. The photo below shows these fittings welded in place. Photographs by courtesy of Downington Iron Works, Downington, Pa.

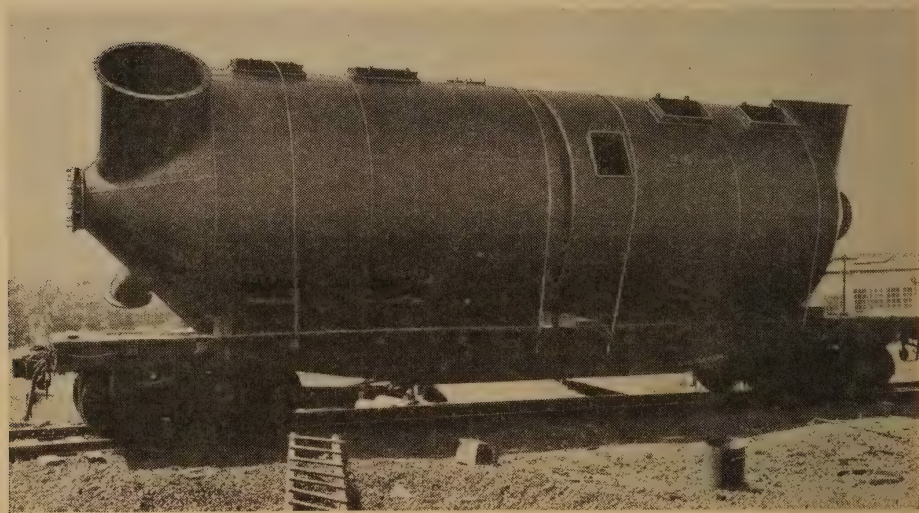


Fig. 32

practice stipulates the following factors of safety for cast iron and steel under various kinds of load.

FACTORS OF SAFETY

Material	Kind of Load		
	Steady	Varying	Shock*
Cast Iron	6	10	20
Structural Steel	4	6	10

The safe working stresses for steel and cast iron in compression, obtained by dividing the ultimate stress by the proper safety factor, are tabulated below:

COMPRESSIVE WORKING STRESS
IN LBS. PER SQ. IN.

Material	Kind of Load		
	Steady	Varying	Shock
Cast Iron.....	15,000	9,000	4,500
Structural Steel....	13,750	9,166	5,500

It is now apparent that for actual working stresses, steel is superior to cast iron for any service where the greatest stress is compression and the load is a typical machine load which varies.

Now let us consider the relative cost of cast iron and steel for compression members. Since steady loads are seldom encountered in machine practice a varying load is taken for this example. Assume a load of 100,000 lbs. to be carried on a block 2 inches thick. A cast iron block to take this load would have to have an area of 100,000/9,000 or 11.1 sq. in. The weight of this cast iron block would be 5¾ lbs. and at 6 cents per lb. would cost 34 cents.

A steel block to take this load would have an area practically the same. The weight of the steel block would be 63 lbs. and at 2 cents per lb. would cost 12.6 cents.

Thus, by substituting steel for cast iron there is a saving of 63% in material cost.

It is apparent from the foregoing that steel is both stronger and cheaper than cast iron for compression members where varying loads are encountered.

Steel is Stiffer Than Cast Iron
in Bending

There is a widespread tradition that cast iron is stiffer than steel, that is, that it deflects less under the same load. The fact is that steel is 2½ times as stiff as cast iron when subjected to bending.

This is shown by the modulus of elasticity of each. The modulus of elasticity of steel is 30,000,000 while the modulus of elasticity of cast iron is only 12,000,000. Translated into non-technical language, this means that if a steel beam carrying a load and sagging a certain amount were changed to cast iron of the same dimensions, the sag of the cast

*Data from "Elements of Machine Design" by O. A. Leutwiler.

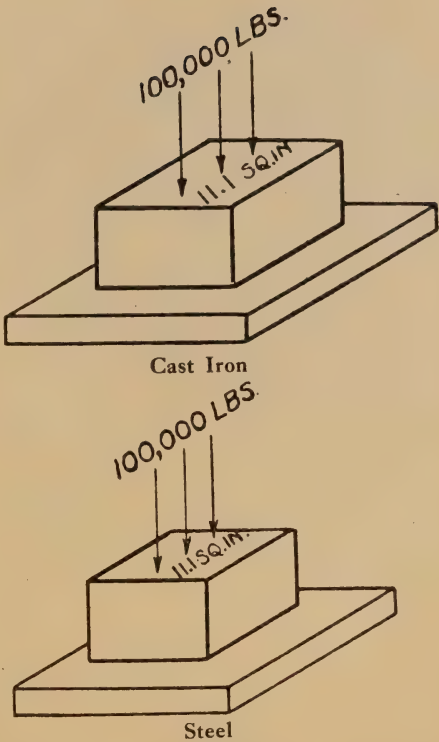


Fig. 33

Steel is more dependable than cast iron in compression and it costs less.
Sections of equal strength

iron beam would be 2½ times as great as that of the steel beam. That is, it would sag 2½ times as much, provided it did not break because of its lesser strength.

Therefore, if a cast iron section in bending were replaced by an equal section of steel, the sag or deflection would be reduced by 60% and the cost would be one-third as much because of the lower cost per pound of steel.

Ordinarily, however, the designer would wish to take advantage of the superior strength and stiffness of steel by reducing the section and thereby making the cost approximately thirteen percent, or a saving of eighty-seven percent if the most efficient steel shape is used for the replacement.

This can be done in practically every instance because any shape which can readily be cast in iron is not of the best design to withstand bending stresses.

Equal Stiffness is Not the Same
as Equal Strength

In substituting steel for cast iron in a part subjected to bending, we must take into account not only the relative areas

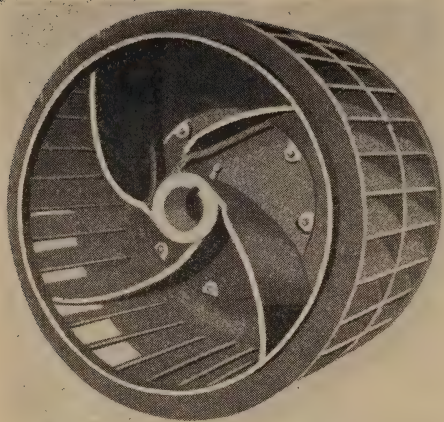


Fig. 34

Arc-welded steel blower fans are lighter than cast iron fans and stronger than riveted steel fans. They are also cheaper to manufacture. Photograph by courtesy of the Robinson Ventilating Co., Pittsburgh, Pa.

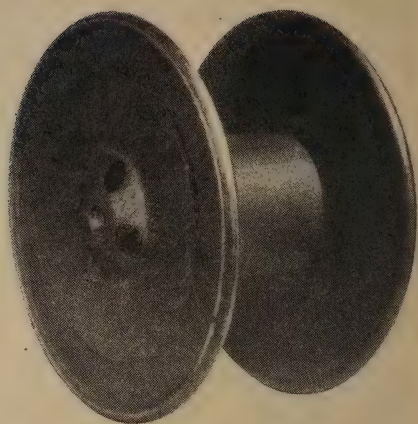
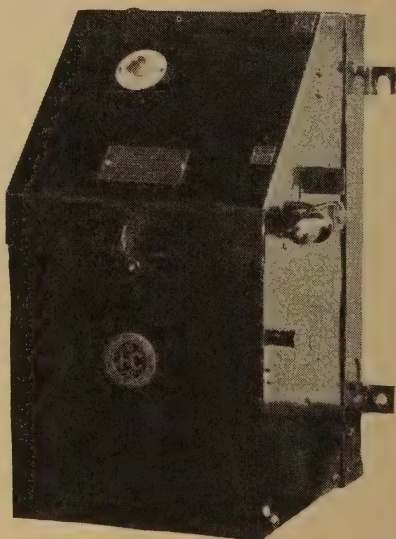
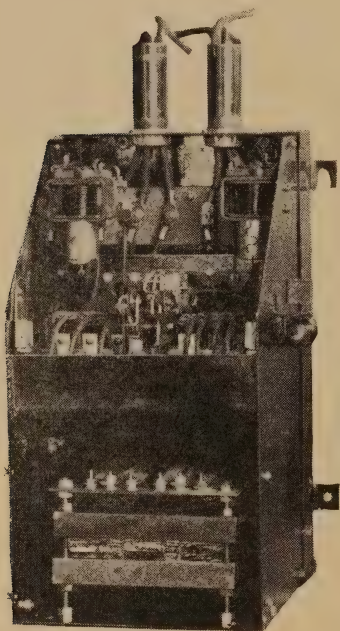


Fig. 35

Welded steel annealing reel manufactured by The American Pulley Company, Philadelphia, Pa.



The Industrial Controller Company, Milwaukee, Wis., make their Compensator Cases of arc-welded steel. This method is cheaper and better than riveting or casting.

of the sections of cast iron and steel, but also the shapes of the sections. It is common knowledge that a board is stronger and stiffer if bent edgewise than if bent flatwise. Strength and stiffness in bending are obtained by keeping the material of the section as far from the center as possible. The I-beam and channel illustrate this principle. Their great strength and stiffness are due to the material in the flanges, located at a distance from the center of the section. This principle is illustrated in Figure 36 where a cast iron section is replaced by three different steel sections, each one having the same vertical stiffness as the cast iron section. While the vertical stiffness is the same in each of the sections illustrated, the weight, working strength and cost vary considerably. These values on a percentage basis are tabulated underneath the sections to which they apply. The effect of changing the vertical and horizontal dimensions separately is clearly shown by this illustration. It is assumed, of course, that when one horizontal dimension is changed, all horizontal dimensions are shrunk in the same proportion. The same assumption is made when vertical dimensions are changed.

Steel is Stiffer Than Cast Iron in Compression

Thus far we have considered the relative stiffness of steel and cast iron only when subjected to a bending stress. Steel is also stiffer than cast iron when

subjected to compression. This is shown by referring again to figure 33, where a load of 100,000 lbs. was assumed to be supported on a block 2 inches thick. Under this load the cast iron would deflect or in other words be compressed 1.8 thousandths inches. The steel block of same area and the same thickness would deflect only .68 thousandths inches. Notwithstanding that the steel block was stressed the same, the deflection is less than one-half that of cast iron.

Steel is Stronger Than Cast Iron in Tension

There remains only to be considered the relative strength and economy of steel and cast iron in tension. The ultimate strength of steel in tension is 55,000 lbs. per sq. in., while that of cast iron is only 15,000 lbs. per sq. in. These are the ultimate or breaking stresses. To determine the working stresses these figures are divided by the proper safety factors which gives the following:

	Tensile Strength	
	Cast Iron	Steel*
Ultimate Strength...	15,000	55,000
Factors of Safety...	10	6
Working Stress....	1,500	9,166
Modulus of Elasticity	12,000,000	30,000,000

These figures show that in tension the allowable working stress of steel is approximately 6 times the allowable working stress for cast iron. This means

*"Mechanical Engineers Handbook"—Marks.

SECTIONS OF EQUAL VERTICAL STIFFNESS

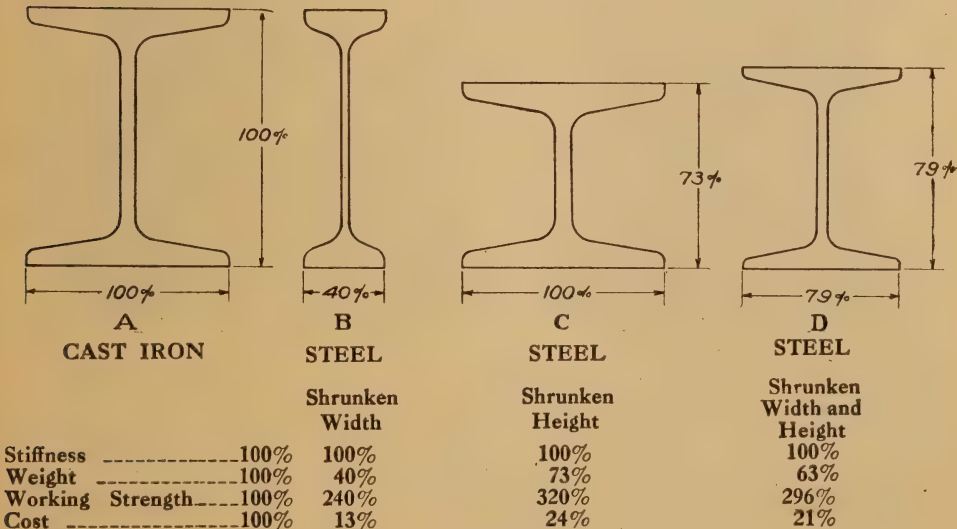


Fig. 36

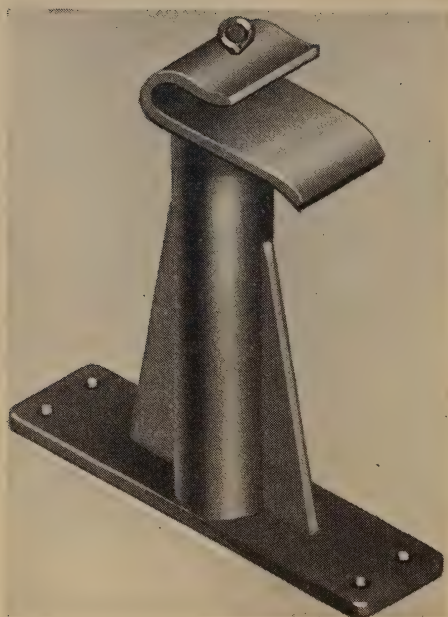


Fig. 37



Fig. 38

Steel has replaced cast iron in countless products used in wire drawing and in the textile industry. Here are two examples made by the Mossberg Pressed Steel Corporation, Attleboro, Mass. Both are arc welded.

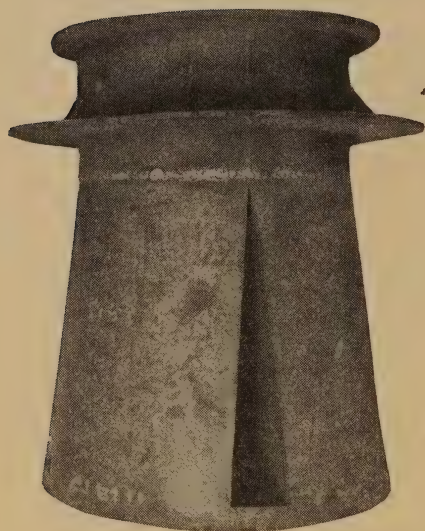


Fig. 39

This arc-welded steel dip pot was formerly made of a casting. There is no excess metal in arc welded construction. Weight is saved and the cost per pound of rolled steel is less than cast iron. Photographs by courtesy of Downington Iron Works, Downington, Pa.

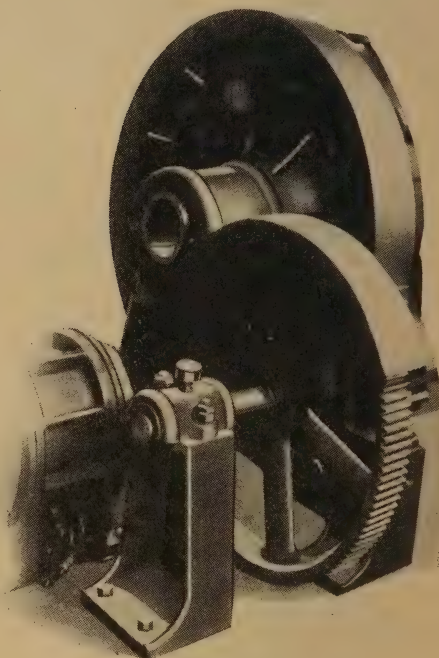


Fig. 40

Gear guards of arc-welded steel are replacing cast iron and riveted steel guards because they are cheaper to make, are lighter and withstand vibration better. Illustration by the courtesy of the Whiting Corporation, Harvey, Ill.

that where *strength in tension* is the only consideration, a cast iron section can be replaced by a section in steel just 17% as large.

Assuming the cost of cast iron at \$.06 per lb. and steel as \$.02 per lb., or 33⅓% of the cost of cast iron, the relative cost of steel is 33⅓% x 17% or 5.66% that of cast iron.

Great care must be exercised at this point because, while steel is 6½ times as strong as cast iron in tension, it is only 2½ times as stiff. This means that when substituting steel for cast iron, it is important to know whether the steel is to be as *strong* as the cast iron section or as *stiff* as the cast iron section. It is

obvious from the foregoing that when a section in tension is cut down to 17% when steel is substituted, that the 17% steel will not be as stiff as the 100% of cast iron even though it is equally strong. Instead, 40% of steel will be as stiff as 100% of cast iron as was demonstrated earlier. The data presented here can be verified in any text book on the strength of materials, and is common knowledge to every engineer.

The fact is that there was no way to cash in on the greater economy of steel until arc welding was perfected because there was no economical method of joining steel shapes. Today, steel can be substituted for cast iron at a saving in nine cases out of ten.

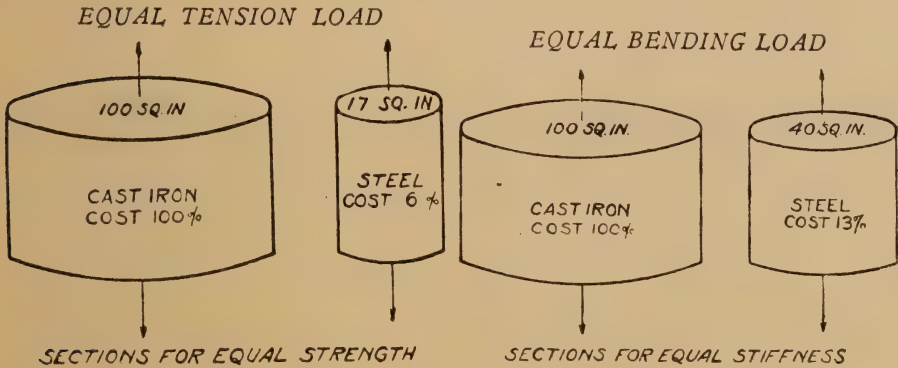


Fig. 41

For equal working *strength in tension*, replace cast iron by 17 percent of that section in steel.

For equal *stiffness of deflection* in tension, replace cast iron by 40 percent of that section in steel.

Table of Comparison of Qualities of Cast Iron and Steel for Machine Parts

	Tension		Compression	
	Steel	Cast Iron	Steel	Cast Iron
Strength	55,000	15,000	55,000	90,000
Allowable working stress including factor of safety—6 for steel, 10 for cast iron	9,166	1,500	9,166	9,000
Cost equal strength including factor of safety	5.6%	100%	32%	100%
	Bending			
			Steel	Cast Iron
			30,000,000	12,000,000
			Same	Same
Modulus of elasticity			13.3%	100%
Allowable deflection				
Cost equal rigidity for shrunk width				

These figures are based on varying load conditions. If the same computation is made for a steady load the ratio of cost of steel to cost of cast iron will be approximately the same. Under a shock load the advantage of steel over cast iron would be even greater.

Here is a Common Sense Problem in Manufacturing Costs and Profits

Suppose you are making a product of cast iron.

If you buy your castings outside:

1. You must pay an average price of 6 cents per lb. for them.
2. Your material cost amounts to a large proportion of your manufacturing cost and of your selling price.
3. Over this large portion of your costs you have no control. Some one else determines what this part of your cost shall be.

The various items which make up the selling price would look something like this.

35 %	8 %	11 %	31 %	15 %
RAW MATERIAL	LABOR	SHOP OVERHEAD	SELLING AND ADMINISTRATION	PROFIT

But if you substitute arc-welded steel for cast iron:

1. Your raw material cost is 2 cents per lb.
2. The weight of raw material required is less.
3. The total cost of raw material is greatly reduced.
4. And a much larger proportion of your total manufacturing cost is under your control.

The various items which make up the selling price would now look like this.

20 %	12 %	12 %	31 %	25 %
RAW MATERIAL	LABOR	SHOP OVERHEAD	SELLING AND ADMINISTRATION	PROFIT

In this example 80% of the total selling price is made up of items over which you have control instead of only 65% as is the case where castings are bought outside. These figures are purely arbitrary, but the principle is correct. Substituting arc-welded steel for cast iron cuts costs and increases profits.

The fact that one's own foundry is used does not solve the trouble since the raw material cost will still be much greater with cast iron than with steel.

CHAPTER II

Arc Welding Makes Riveting Obsolete

THE sky-scraper, the huge bridge, the ocean greyhound of the future, will each be safer and stronger because of arc welding. Instead of being constructed of many separate plates and shapes pegged together with rivets, the frame work of each will be one solid piece of steel welded into a homogeneous

whole by the magic of the electric arc.

Like the famous one-horse shay, each part will be as strong as the next because in arc-welded construction the joints are as strong as the members to be joined. This is not possible in riveted construction.

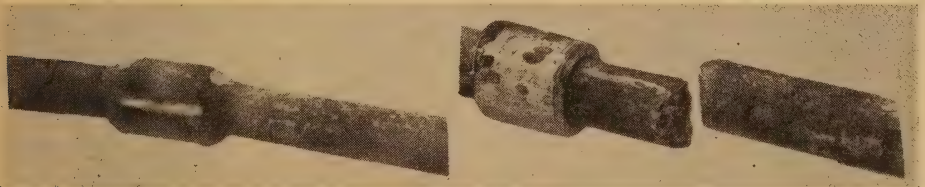


Fig. 43

Arc-welded steel bridge in Toronto, Ont. The steel frame work carries the entire load, concrete is used solely as a protection for the steel. The detail shows methods of butt welding the members. As an additional precaution a collar was slipped over the joint and welded in place. The cost of the arc-welded construction was far below that for any other type of construction.

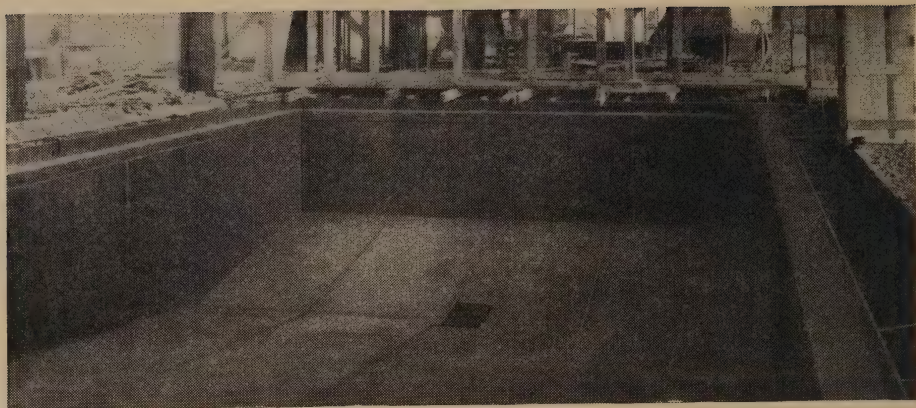


Fig. 44

Arc welded swimming pool in the new Standards Club, erected by the Graver Corporation, East Chicago, Ill.

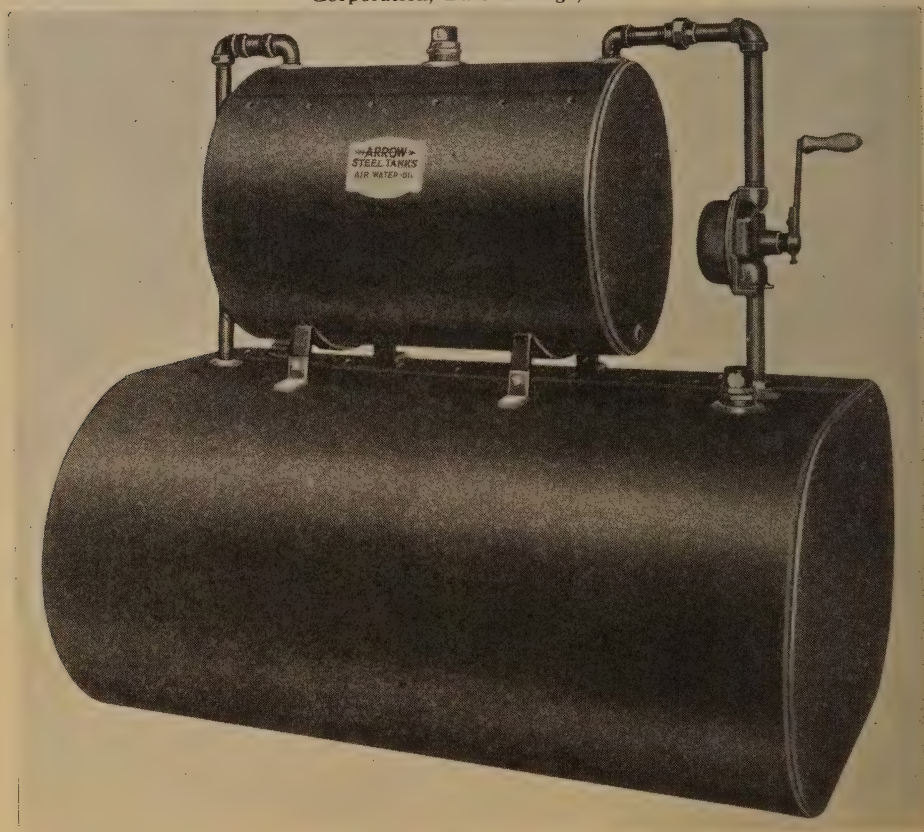


Fig. 45

The storage tanks for fuel oil, gasoline and distillate manufactured by The Novelty Steam Boiler Works Co., Baltimore, Md., are unconditionally guaranteed. Heads and girth seams are arc-welded.

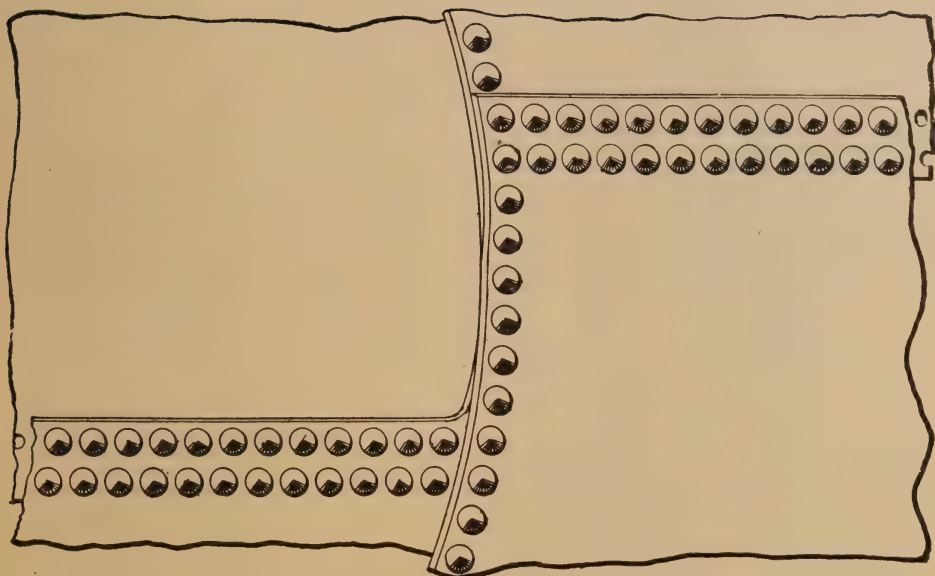


Fig. 46

Rivet holes weaken the plates where the strength is needed most.

Every Rivet Hole Weakens a Structure

At present when a boiler or tank is built to withstand high pressure, the best steel that can be rolled is selected. This steel is then taken to the fabricating shop where it is robbed of its strength by the punching of hundreds of rivet holes. It is weakened where its strength is needed most,—where it is riveted to the adjoining plates.



Fig. 47

Arc welding utilizes the full strength of the metal. No part of the strength is punched out. This ammonia tank was made by the Frick Co., Waynesboro, Pa.

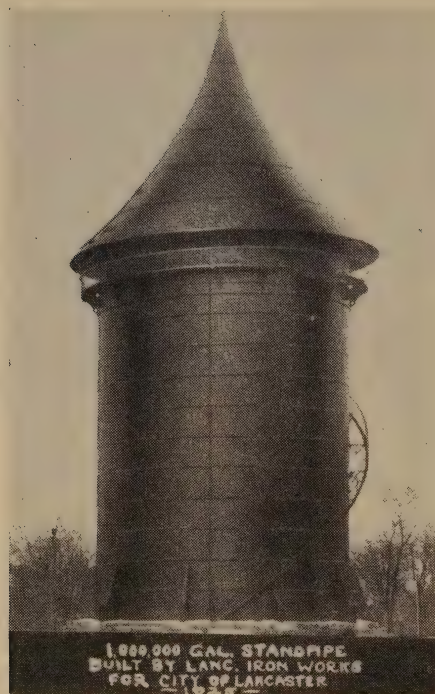


Fig. 48

This 1,000,000 gallon stand pipe towers one hundred and twenty-seven feet in the air. It is a familiar land mark to the residents of Lancaster, Pennsylvania. And it is likewise an impressive monument to the integrity of arc welded construction. Welding was done by The Lancaster Iron Works.

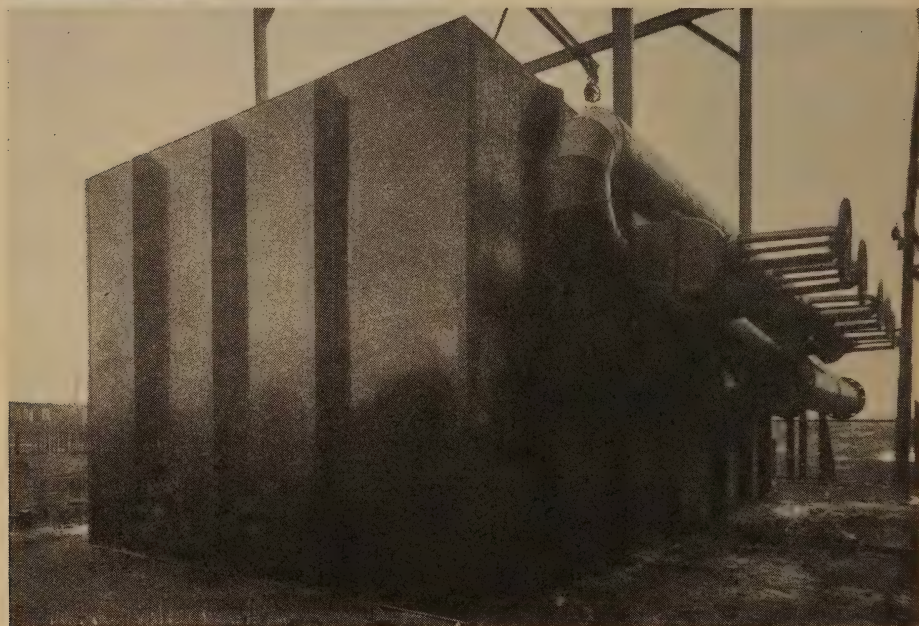


Fig. 49

This purifier box for the Granite City Gas Light and Fuel Co., Granite City, Ill., was erected complete in the field by Electric Arc Welding. Built by Steere Engineering Company, Detroit, Michigan.

●

cation of each rivet hole indicated.

Energy is wasted in the drafting room where each riveted joint must be carefully figured, the size of each rivet determined and the lo-

Energy is wasted in the template shops where full size cardboard, wood or metal patterns of every structural member are made and every single rivet hole located so accurately that when assembled each hole will register with a hole in one, two, or three other members.



Fig. 50

Think of the time wasted in laying out and punching the rivet holes in this structure.
Welding will eliminate this waste.



Fig. 51



Fig. 52

Arc welding is replacing riveting in the manufacture of air ducts, ventilators, smoke breechings, conveyor housings and similar products. Here are two examples arc welded by Leitelt Iron Works, Grand Rapids, Mich.

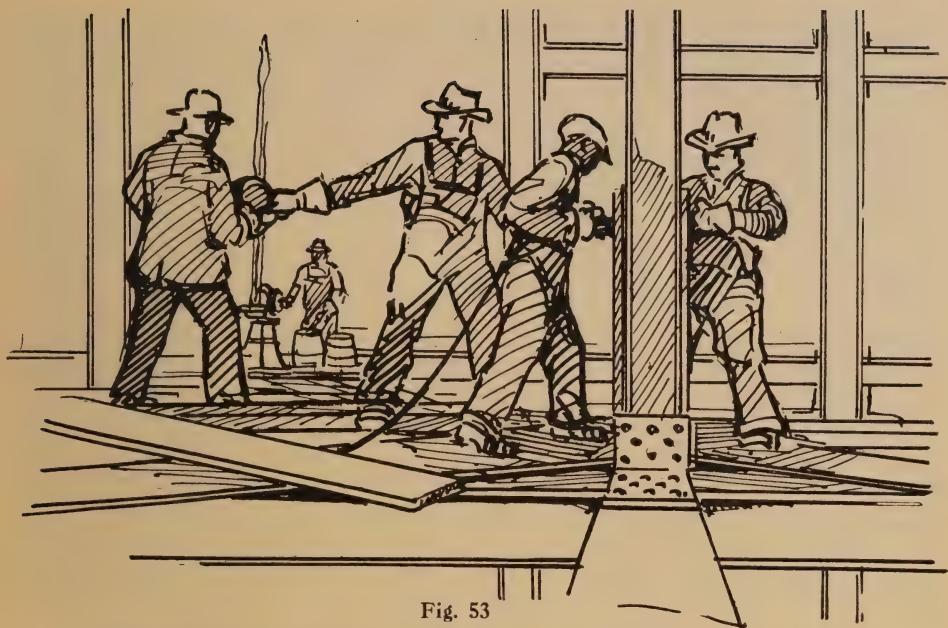


Fig. 53

Driving rivets is laborious and slow, requiring from three to five men per crew.

This work requires infinite care, infinite skill—and all is unnecessary.

More energy is wasted in punching the rivet holes, which not only weaken the members, but which also require expensive equipment and labor. There is the tremendous economic waste of making every member larger and heavier than necessary throughout its entire length solely to provide the required strength at the ends where the rivet holes have weakened the member.

Energy is wasted in driving rivets both in the shop and in the field—work that is slow and laborious and which requires expensive equipment.

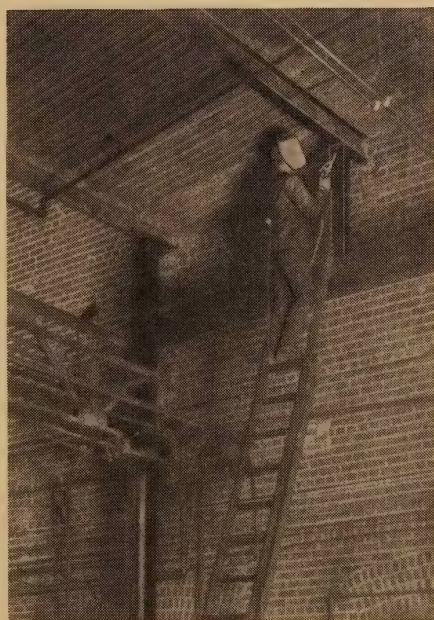


Fig. 54

One welder does the work of riveter, catcher, heater and bucker-up.

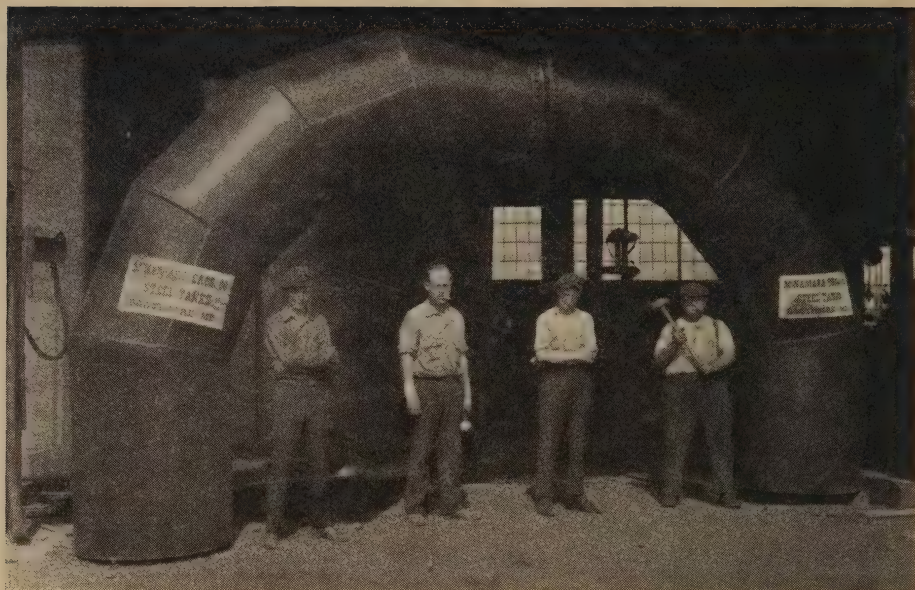


Fig. 55

Think of the time and money that it would have taken to rivet together this irregular-shaped pipe! McNamara Bros., Baltimore, Md., arc weld tanks of all kinds. An arc welded tank requires no calking and the joint is as strong as the plates joined.



Fig. 56

Arc Welding Saves Material Where Joints Are in Tension

An arc welded joint is as strong as the members joined.* No part of the strength of the steel is punched out. The plates or beams at the joint are up to full strength. Consequently, it is not necessary to make the members heavier throughout their length to provide for weakness at the joint as is the case in riveting.

It is possible to make tanks stronger by arc welding than by riveting, using the same weight of material, or it is possible to obtain equal strength with less material.

If this saving in material were the only advantage of arc welding, its importance is so great that this modern method would replace the old-style practice.

*See discussion of comparative strength of welded and riveted joints on page 115.

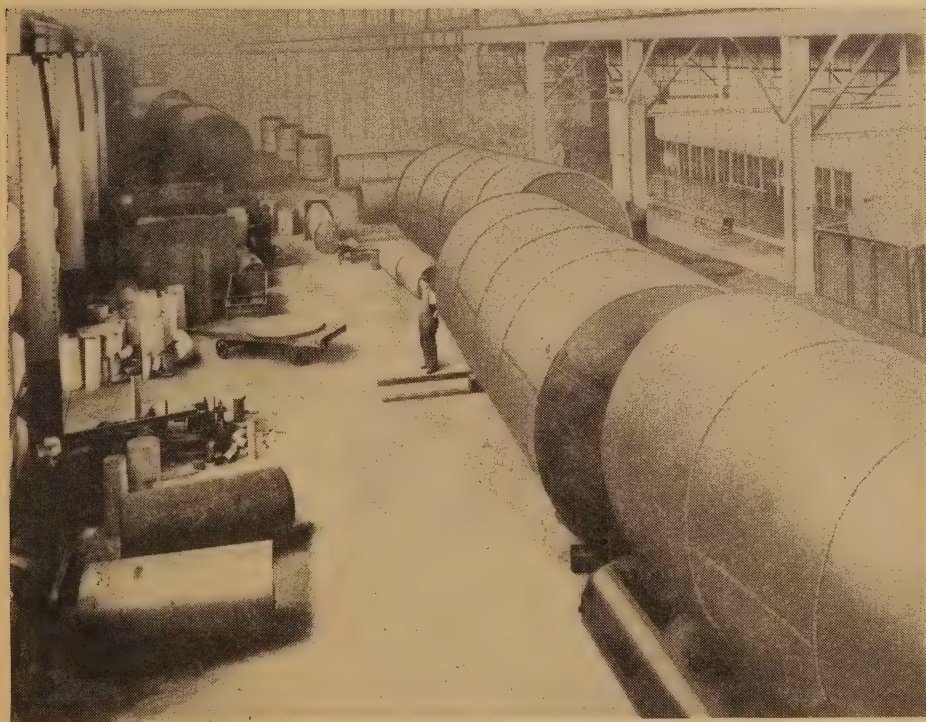


Fig. 57

No tanks are too large to be arc welded. This picture was taken at the Heil Co., Milwaukee, Wis.



Fig. 58

There are 103 arc welded girders in this building. Albert Kahn, Inc., Architect.

Where Arc Welding Has Replaced Riveting

The substitution of arc welding for riveting is not a vision of the future, it is used today on the very examples given above, steel buildings, bridges and ocean-going vessels.

In Detroit, the steel framework of a 12-story addition to the Peoples Outfitting Company building is arc welded where the floor girders frame into the columns. In Canton, a building for the Peerless Motor Sales Company was constructed of arc welded steel at an estimated saving over riveting labor cost of approximately 25%.

In the Province of Ontario, a highway bridge of three spans, 500 feet overall, carrying the heavy traffic into the city of Toronto, was constructed in 1923, of arc welded steel and concrete. The design of the bridge is unique. All of the

steel work is made up of round bars. The steel carries the entire load, the concrete serving solely as a protection for the steel. Before this bridge was built the design was severely criticized by engineers not familiar with the possibilities of arc welding. However, the designer knew what could be accomplished. The bridge was built, and it met all required tests, and it was built at a cost far below that of riveted construction.

Sea-going vessels and lake boats have been built complete by arc welding, both in this country and abroad. Today, that conservative arbiter of ship construction, Lloyd's Register of Shipping, is permitting the wider application of arc welding, as repeated tests demonstrate its especial fitness and economy.

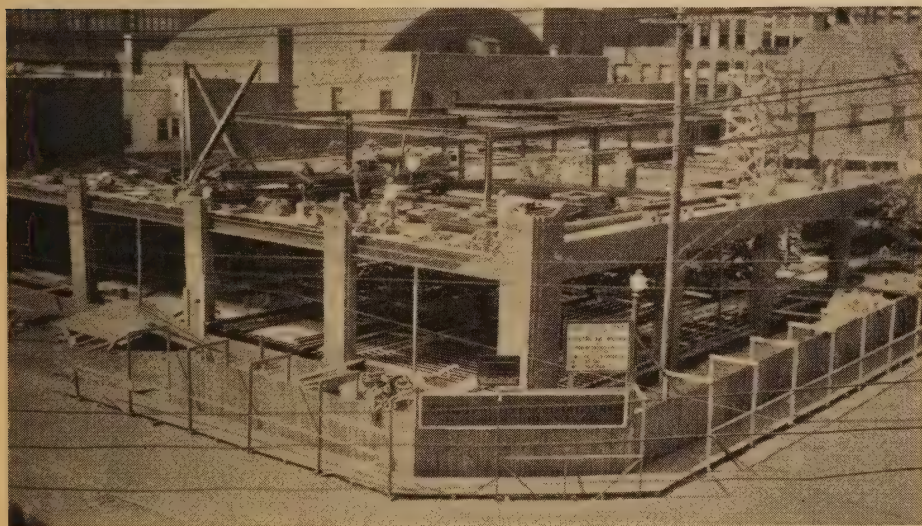


Fig. 59

Peerless Motor Sales Co., Canton, O. Not a single rivet was used in the construction of this building. All of the steel work is arc welded. The Morgan Engineering Co., Alliance, O., were pioneers in adopting arc welding for heavy structural work.

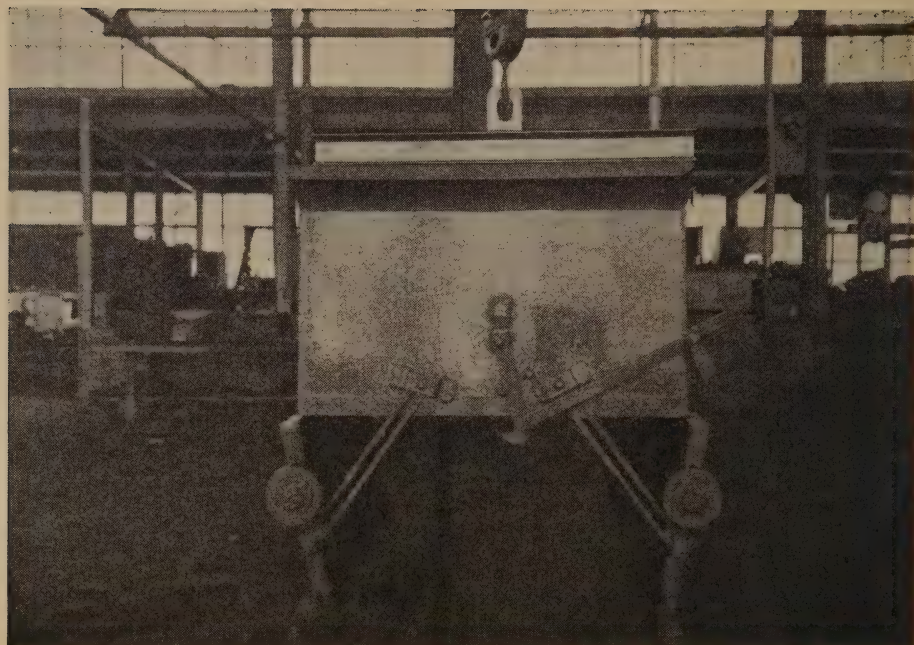


Fig. 60

Two views of Bottom-dump bucket used for handling rubber. Completely arc welded by The Cleveland Crane & Engineering Co., Wickliffe, Ohio.

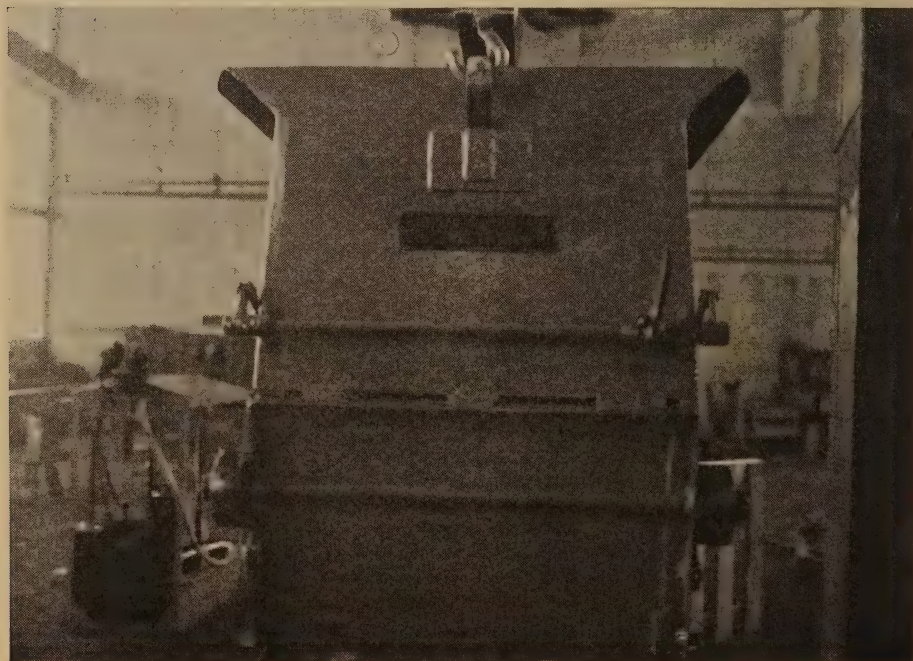


Fig. 61

Welding Makes a Better Product at a Lower Cost

It is not only on large spectacular work that arc welding is replacing riveting. The relative savings are equally important in many production industries for welding gasoline tanks, automobile truck bodies, burial vaults, coal weighing hoppers, concrete mixers, truck frames, water tanks, etc.

If it can be riveted it can be arc welded cheaper, faster and better. The following pages show a few of the many arc welding applications. It is manifestly impossible to show more than a small percentage. In

looking over these applications, bear in mind that arc welding was adopted because it saved the manufacturer money, and made a better product. Most of the manufacturers of these products advertise the fact that their products are arc welded, because the public is beginning to realize that a welded product is a superior product.

Whatever you manufacture, if iron or steel plays a part in it, arc welding can probably be applied to advantage. If your product is not arc welded now, it will be either by your company or your competitor.

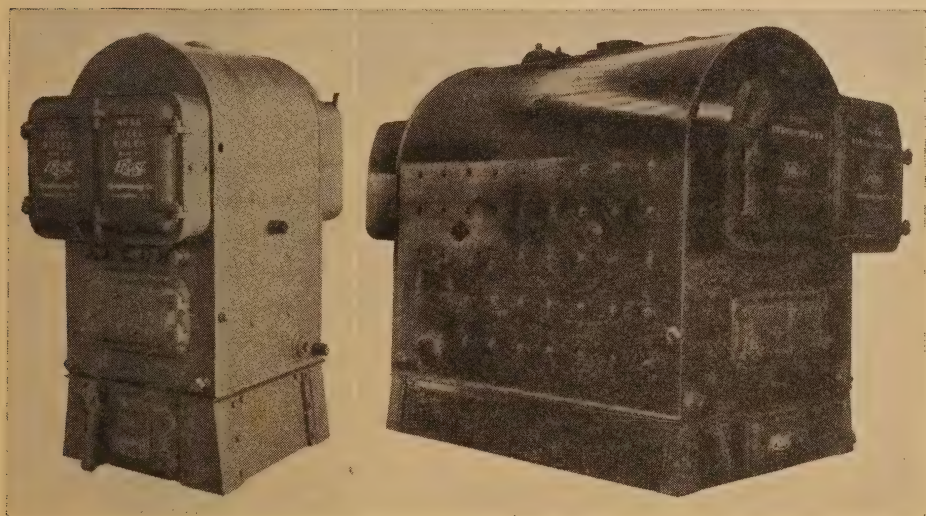


Fig. 62

Every joint between plates, every outlet flange and every stay bolt on the Ross Steel Boiler is arc welded. Ross Boilers are built for 30 lbs. working pressure but are tested to 50 lbs. pressure which is practically the rupture point of the plates. The Ross Boiler is built by the Frost Manufacturing Co., Galesburg, Ill.



Fig. 63

An arc-welded product is a superior product. Note the representative manufacturers who feature welding in their advertising.

CHAPTER III

What Arc Welding Is and What It Does

THE startling claims made for arc welding in the preceding pages of this manual are almost beyond belief. To eliminate casting and riveting—two fundamental manufacturing processes—would seem to be a wild and impossible vision, but that is exactly what arc welding will accomplish. Doubtless one's first thought will be, that to bring about such revolutionary changes, arc welding must be a complicated process requiring elaborate equipment and great technical skill for its operation. Fortunately this is not the case.

Before taking up in detail the manner in which arc welding is utilized in manufacturing, it will be well to describe briefly just what arc welding is and what it does.

There is nothing mysterious about the process. The edges of the parts to be joined are brought to the proper welding temperature and fused together. The heat required to fuse the metal is developed by an electric arc.

An electric arc is nothing more than a sustained spark between two terminals or electrodes. In arc welding, the arc is formed between the work to be welded and an electrode held usually in the operator's hand.

The hand electrode may be either a metallic wire or a carbon rod. Either is held in a suitable electrode holder as illustrated in figures 67 and 68. When the metallic electrode is used the process is spoken of as metallic arc welding, and when a carbon electrode is used the process is called carbon arc welding. Both methods have their particular application as explained below.

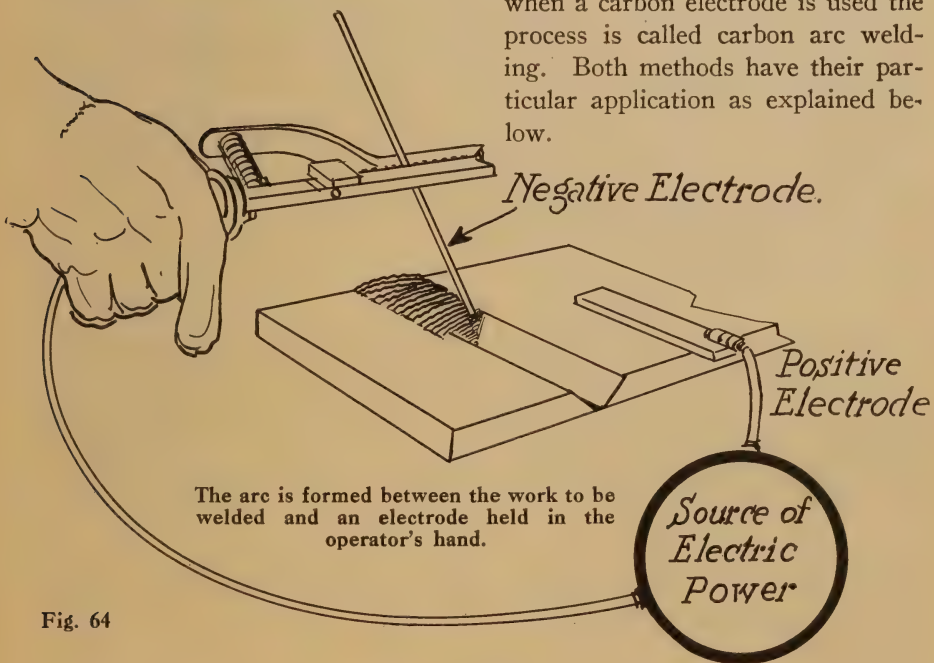


Fig. 64



Fig. 65

There are three ways in which this base for an excavating machine can be made. One is by a steel casting, the second by riveted sections and the third by arc-welded sections. The arc-welded construction is stronger than riveted construction and lighter than a casting of equivalent strength.

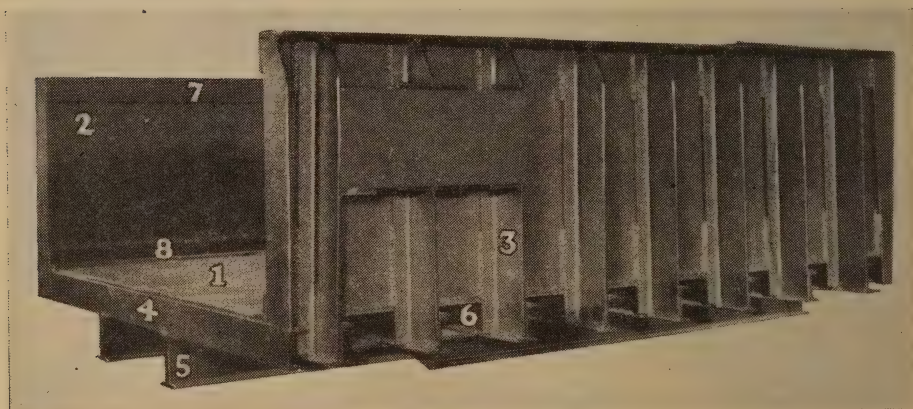


Fig. 66

Rocks weighing more than 1-ton each will be dropped 3 to 4 feet into this heavy-duty truck body. It is one of four similar bodies used by the Dolomite Products Company for handling rock from electric shovel to crusher.

These bodies were designed and arc welded by the Genesee Bridge Company, Inc., Rochester, N. Y.

The figures refer to the standard steel shapes used to make this body:

- | | |
|----------------------------------|---|
| 1. $\frac{3}{8}$ " Bottom Plate. | 5. 4" x 10.5 lb. I-beam. |
| 2. $\frac{3}{8}$ " Side Plate. | 6. Ditto. |
| 3. 4 x 5 x $\frac{3}{8}$ Tee. | 7. 4 x 4 x $\frac{1}{2}$ Angle. |
| 4. 4" x 7.25 lb. Channel. | 8. 2 $\frac{1}{2}$ x 2 $\frac{1}{2}$ x $\frac{3}{8}$ Angle. |

Metallic Arc Welding

In this process the arc occurs between the work to be welded and a metallic wire. Under the intense heat developed by the arc a small part of the work to be welded is brought to the melting point almost instantaneously. The other end of the arc, the tip of the metallic wire, is likewise melted and a globule of molten metal forms. This globule is then *carried* across the arc and deposited in the molten seat waiting for it in the work. The globule is actually carried across the arc and not dropped as gravity does nothing more than assist this deposition of metal when the work is flat. The fact that this globule of molten metal will be deposited overhead against the force of gravity is proof

that the process is one of deposition. It is this fact which permits the use of metallic arc welding in overhead welding which is impossible by any other process.

Carbon Arc Welding

In carbon arc welding the arc is formed between the work and a carbon rod held in the electrode holder. The heat of the arc melts a small pool in the surface of the work to be welded. This pool is kept molten by playing the arc across it and extra metal is added by a filler rod to form the weld. Carbon arc welding is a puddling process, and is not applicable to vertical or overhead welding. Its greatest application is in automatic welding or in welding heavy sections where much heat is required.



Fig. 67

Metallic Electrode Welding. The electrode in this case is a metal wire of small diameter and this wire gradually melts itself away, furnishing metal for the weld.

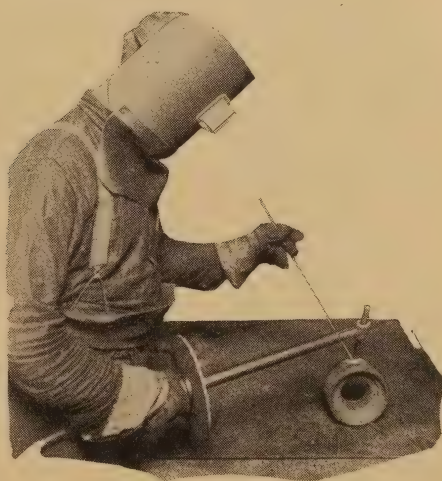


Fig. 68

Carbon Electrode Welding. The operator holds the carbon electrode with the right hand and feeds the filling metal into the weld from a rod held in his left hand.

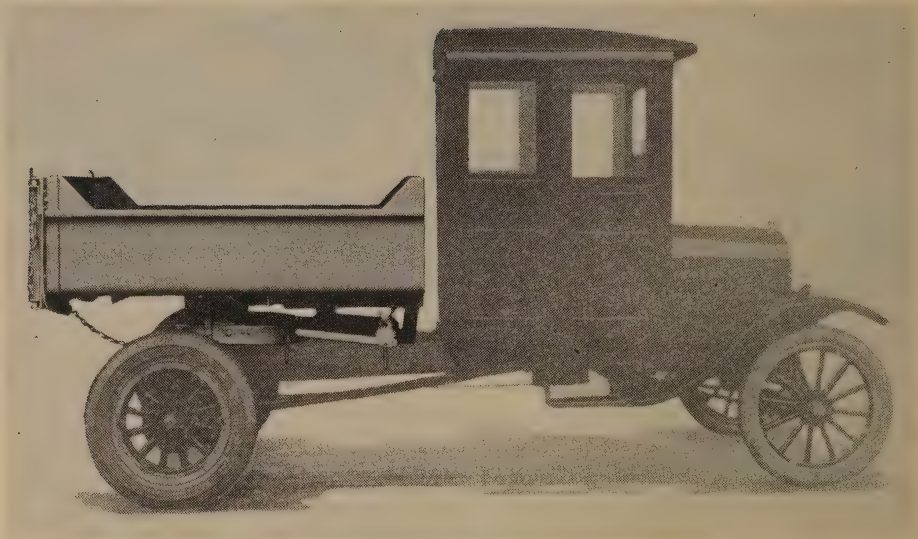


Fig. 69

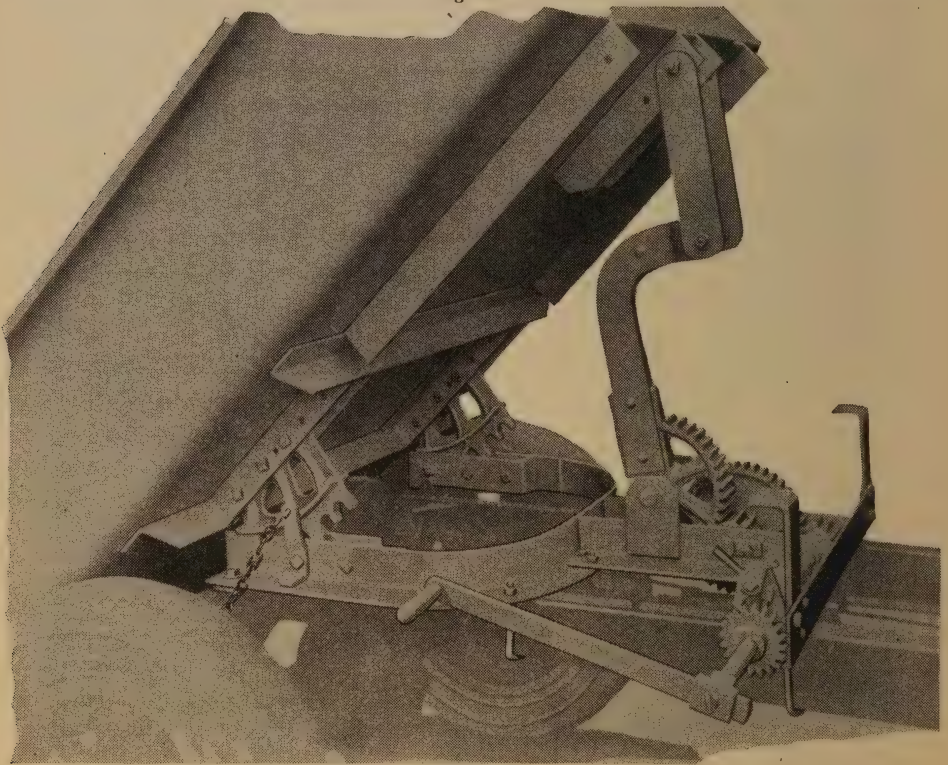


Fig. 70

All steel dump body for Ford truck, manufactured by The Galion Allsteel Body Co., Galion, Ohio. Arc welding has superseded riveting wherever a permanent joint is required.

The Simplicity of Arc Welding

An arc welder usually represents an investment of less than \$1000 and takes up about 15 square feet of floor space. Any workman capable of learning to set up work on a lathe or milling machine can learn arc welding in a comparatively short time.

The current used for arc welding is of a lower voltage than that used on a house lighting circuit and is en-

tirely safe in the hands of an ordinarily skilled man. Adjustments or repairs which may be necessary can be made by an electrician. The equipment is simple in construction and in principle requires very little attention other than oiling. Complete data on various styles of arc welders and on the speed and cost of welding will be found in subsequent chapters.

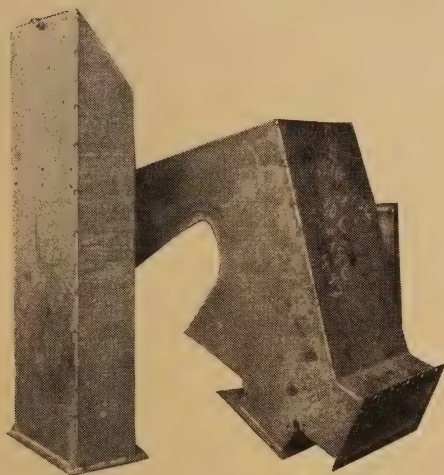


Fig. 71

Miscellaneous parts are welded by The Link-Belt Co., Philadelphia, Pa.

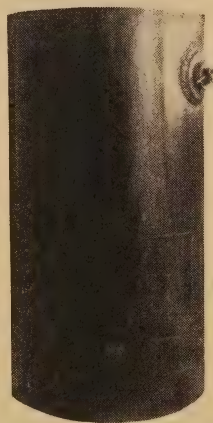
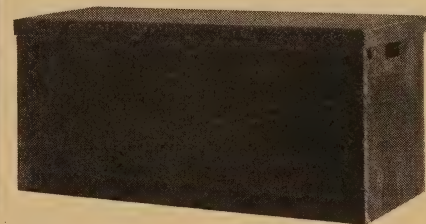


Fig. 72



Keystone Driller Co., Beaver Falls, Pa., arc weld round and square tanks as well as other equipment for the oil industry.



Fig. 73

Air pipe completely arc welded by Littleford Bros., Cincinnati, Ohio. Other products arc welded by this company include: Jacketed pressure tanks, fuel oil tanks, underground storage tanks, air preheaters, gear guards, lathe pans, conductor piping hoppers, chutes and other power plant equipment.

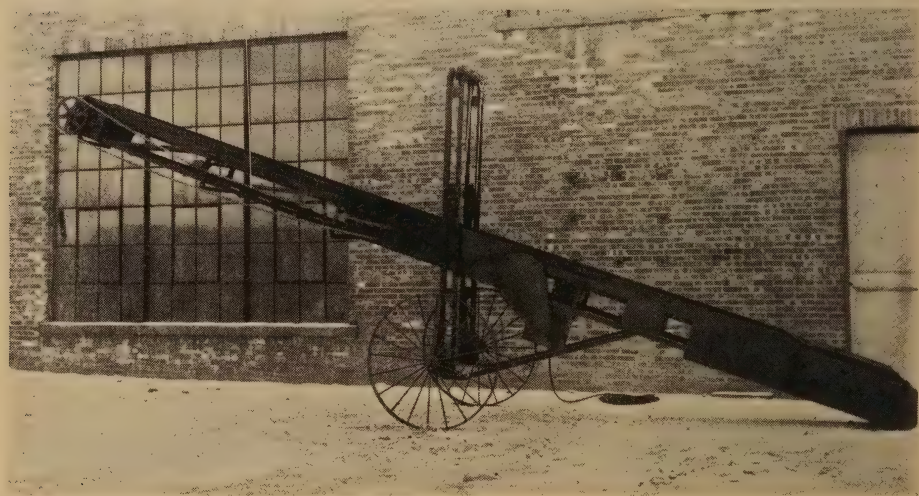


Fig. 74

Portable conveyor manufactured by The Fairfield Engineering Company, Marion, O. The vertical members are arc welded to the axle, and arc welding is used on side shields, gear covers and cross frame members.

How Steel is Joined by Arc Welding

In joining steel by arc welding the metal deposited by the metallic electrode, or added by the filler rod in the case of carbon arc welding, unites with the steel and forms a solid integral joint.

The metal added to form the weld is of the same chemical composition as the steel parts to be welded. It has the physical characteristics of cast steel.

While the tensile strength of cast steel is less than that of rolled steel, it is possible by depositing enough additional metal to build the strength of any joint up to the strength of the parts joined. A complete discussion of the strength of welded joints will be found in pages 111 to 121 inclusive.

There are four different ways of joining steel plates by arc welding. These are:

1. The butt weld.
2. The lap weld
3. The fillet weld.
4. The rivet weld.

Two styles of *butt weld* are illustrated in figures 75 and 76. The edges of the two plates are butted together and the weld made by depositing the welding metal along the edges. In metallic arc welding, when the thickness of the plates is greater than 10 gauge, it is desirable to scarf or bevel the edges as shown. (No scarfing is necessary when carbon electrodes are used.) The plates may be double beveled

or single beveled. This type of joint is the most economical from the point of saving material.

A *single lap weld* and a *double lap weld* are illustrated in figures 77 and 78. One piece is lapped over the other and the welded metal is deposited along the edges as shown. The double lap weld is used where maximum strength is required.

The *fillet weld* is really a modification of the butt weld. Figure 81 shows how the metal is deposited to form the weld. This method of construction has a wide range of applications. It avoids the use of



Fig. 75

Butt Weld—Single bevel.



Fig. 76

Butt Weld—Double bevel.



Fig. 77

Single Lap Weld.



Fig. 78

Double Lap Weld.

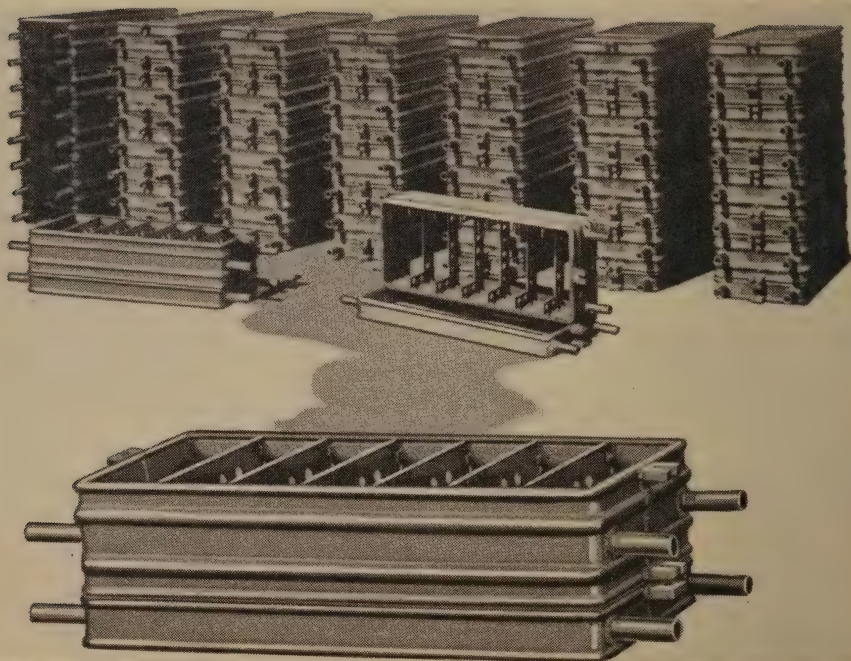


Fig. 79

Until it was definitely proven that an arc-welded steel flask was superior in every way to a riveted steel flask, The Shanafelt Manufacturing Co., Canton, Ohio, produced both. Now their entire output is arc welded. Shanafelt steel flasks are made in many sizes and styles to meet all requirements.

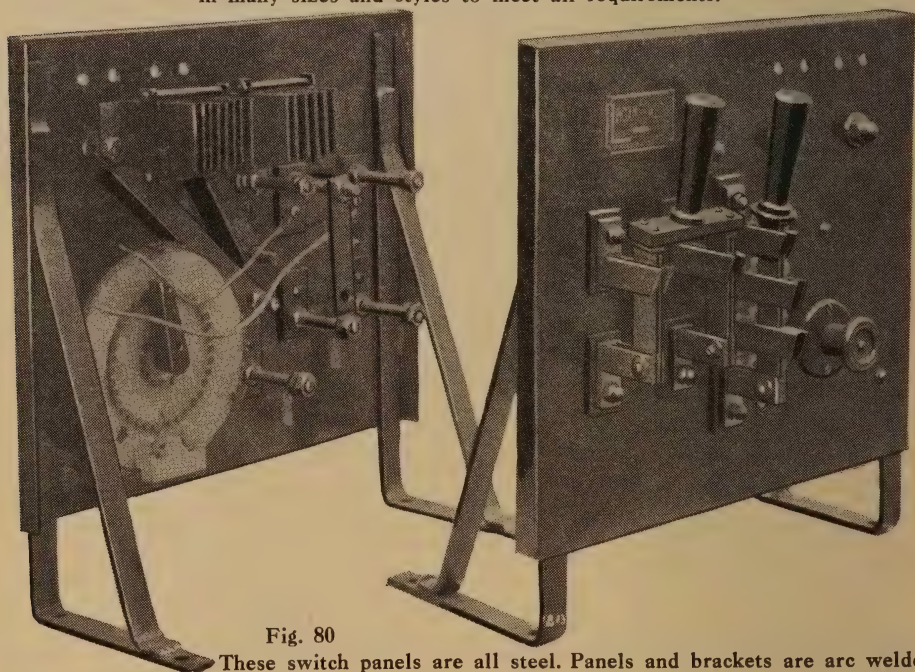


Fig. 80

These switch panels are all steel. Panels and brackets are arc welded.

flange angles which are required in riveted construction.

The *rivet weld* is used where it is not feasible to use a lap weld or a butt weld. Holes are drilled or punched through one of the pieces. This piece is placed against the piece to be fastened to it and the welding metal is deposited in the holes. A solid plug of steel which is completely welded to both members is the result. This type of construction is exceedingly useful when metal cannot easily be applied on the edges of the parts to be joined. This construction has many advantages over ordinary riveted construction. The rivet weld will not loosen under a weaving strain because the welding metal is integral with the parts joined. Since holes are made in only one of the members there is no difficulty in registering. Therefore no laying-out or templates are required. Furthermore there are

no protruding heads as in ordinary riveting.

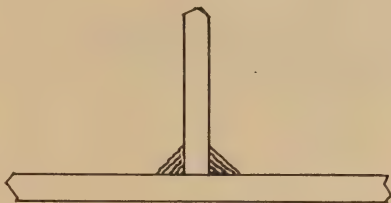


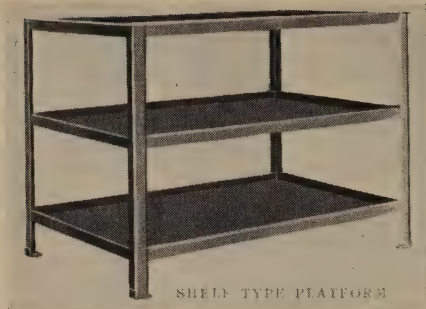
Fig. 81
Fillet Weld.



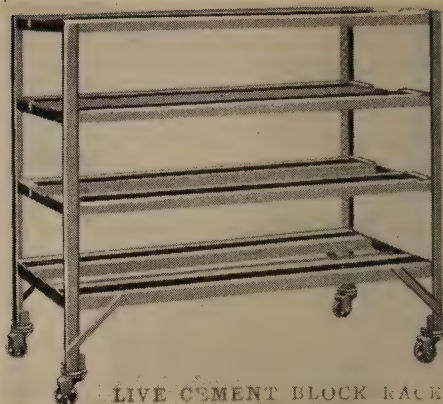
Fig. 82
Rivet Weld.



Fig. 83
Truck body manufactured by the Truck Equipment Co., Buffalo. N. Y.



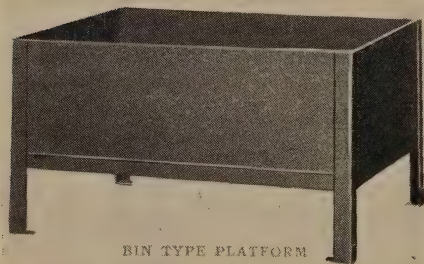
SHELF TYPE PLATFORM



LIVE CEMENT BLOCK RACK

Fig. 84

Platform and racks for use in manufacturing plants must be strong enough to withstand hard use and light enough to be transported easily. Here are three styles which meet these conditions. Arc-welded by Lewis Shepard, Boston, Mass.



BIN TYPE PLATFORM

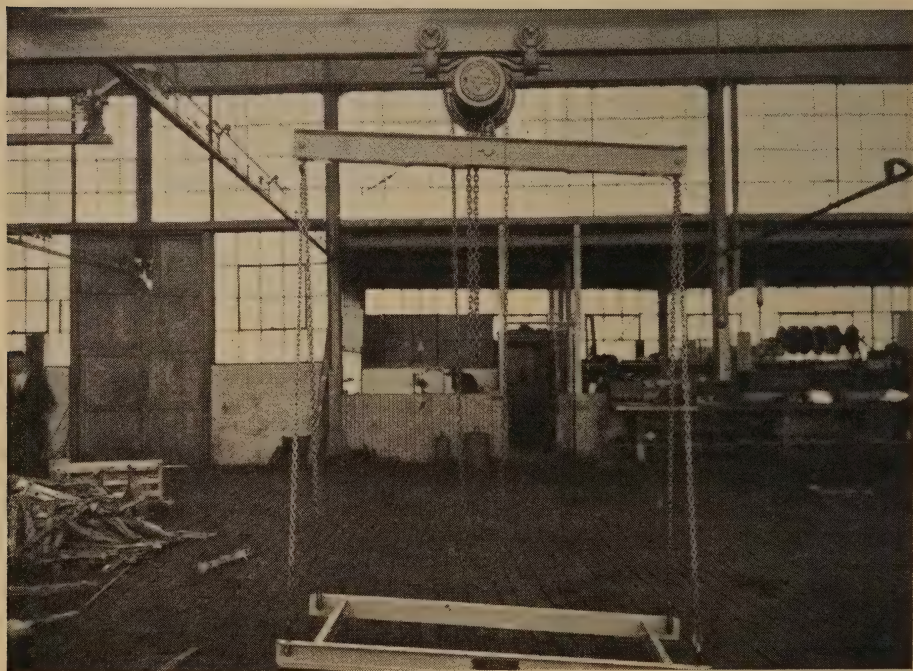


Fig. 85

Arc welded skid grab for handling paper. One of many applications of arc welding made by The Cleveland Crane & Engineering Co., Wickliffe, Ohio, in the manufacture of material handling equipment.

ADDENDA TO CHAPTER III

Other Methods of Welding

As a matter of interest a brief description is given here of other methods of welding which have a more limited range in general manufacturing. Each method has its field but none of them can approach arc welding in speed, economy, dependability, or all around utility.

There are four other methods of welding, differentiated chiefly by the method of heating the work. These are:

1. Forge or fire welding.
2. Thermit welding.
3. Resistance welding.
4. Oxy-acetylene or gas welding.

Forge welding is the method of the blacksmith shop. The metal is heated in the forge and hammered on the anvil. Because of its cost and obvious slowness this method is not a process which can be used widely in production manufacturing. For certain classes of work this process has been improved by the development of heating furnaces and power hammers. The range of applications, however, is extremely narrow. In structural steel construction as used in building it is obviously out of the question to use forge welding.

Thermit welding is essentially a casting process. The heat is produced by the chemical combination of iron oxide and powdered aluminum. When this mixture is ignited it generates tremendous heat and releases molten metal which unites with the parts to be joined thus forming a weld. It is necessary to provide moulds to confine the molten metal the same as in any casting process. Thermit welding has a certain usefulness in the repair of heavy parts but because of the necessity for moulds and dams it is not practicable for production welding.

In resistance welding the necessary heat is produced by an electric current. In this process the pieces to be welded are placed in contact and an electric current passed across the junction. Be-

cause of the imperfect contact the resistance to the passage of the electric current is high. The heat produced by this action causes the metal at the junction to become plastic and when the desired plasticity has been reached the pieces are forced together and a weld results. This process is used chiefly in spot welding of surfaces usually of rather light material. It has a limited application in general manufacturing.

In oxy-acetylene or gas welding a flame produced by the burning of oxygen and acetelyne is played upon the surfaces to be joined and the extra metal is added to the junction by the melting of a filler rod of suitable composition. Gas welding has a wide application in repair work where the amount of welding is not large. It is also used to a certain extent in general manufacturing.

Notwithstanding the comparatively low first cost of equipment, the high operating cost makes it less economical than arc welding for production work.

It is very difficult to weld vertical seams or overhead seams because gas welding is a puddling process. That is, the molten metal forming the weld is in a small pool over which the flame is constantly played. Making a weld consists largely in causing this pool to move by melting metal away ahead of the pool and letting the metal cool behind it.

A further disadvantage of gas welding is the fact that the heat is applied to the metal externally. The flame rebounds and spreads considerably away from the locality where the weld is to be made. This frequently causes warping of the parts unless elaborate precautions are taken which necessarily increase the cost. The cost of the heat used by this process is about three times as great as with the arc process and less than one-third is used in the weld—the rest is blown away by the action of the flame itself.

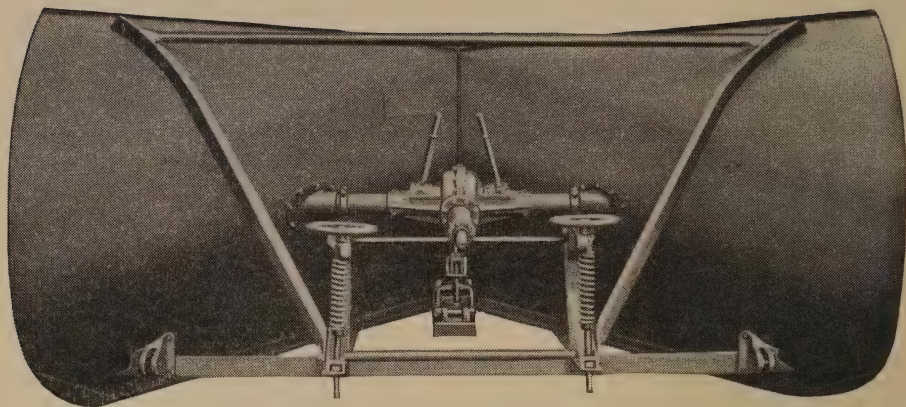


Fig. 86

Snow King, the rotary snow plow manufactured by the Imperial Machine Company, Minneapolis, Minn. Arc welding accounts for the sturdy strength of this machine.

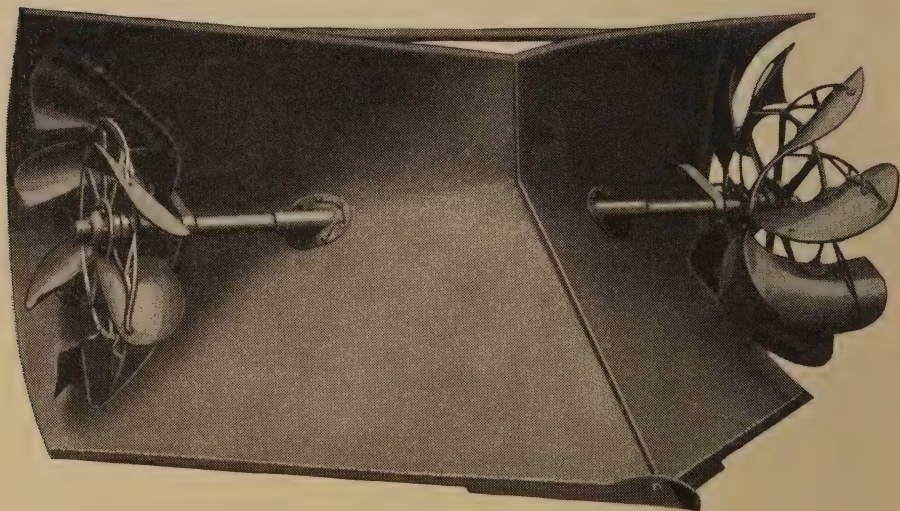


Fig. 87

The cutting edge, stiffener braces and rotor blades are all arc welded. Notwithstanding the severe service which the rotor blades encounter, such as striking rocks and fence posts, there have been no failures of the welds.

CHAPTER IV

Arc Welding in General Manufacturing

THE shop superintendent or the designer who does not know arc welding is probably losing money for his firm. He is authorizing drilling, punching, reaming, bolting and riveting where arc welding will do the work better and cheaper. He is using iron castings where arc-welded steel would be cheaper and stronger.

The arc welder is a production tool. In modern manufacturing it is as fundamental as the lathe, the drill press or the milling machine. It is just as important for the up-to-

date designer to know arc welding as it is for him to know the fundamentals of forge shop practice or machining methods.

Firms that have been the first to redesign their products for arc welding are reaping the profits which come from lowered costs. The wide range of products illustrated in this book barely indicate the possibilities of this process. New applications are being made daily and every new application means that some one has found a way to make his product better, or to make it at a lower cost.

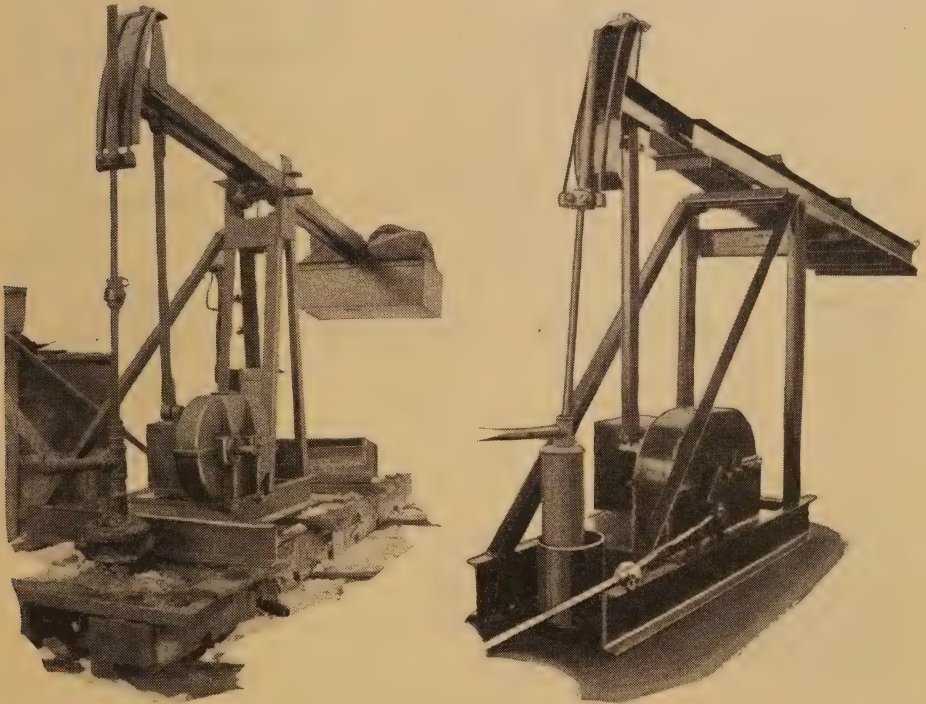


Fig. 88

Well pumping rig redesigned for strength and economy. The left hand picture shows riveted construction with cast-iron pump housing. The right hand picture shows the same equipment built of arc-welded steel. Photographs by courtesy of American Crane Co., Friendship, N. Y.



Fig. 89

Use standard steel shapes. Many styles and sizes are carried in stock.
Above are only a few of them.

Redesigning for Arc Welding

When the engineer comes to realize that welded joints are stronger than any other method of joining metals and at the same time the least expensive he will have learned the most important step in redesigning for economy.

The next important step is the realization that practically any part that can be made in cast-iron can be made up of standard steel shapes

welded together. At first glance this seems almost unbelievable but a thorough analysis will prove the truth of this statement. Steel shapes are available in a wide variety of styles and sizes. A few of these are reproduced in figure 89. It is sometimes necessary to bend or roll these standard shapes to produce the part required, but steel has such a large price advantage over cast iron that this can usually be done at a saving.

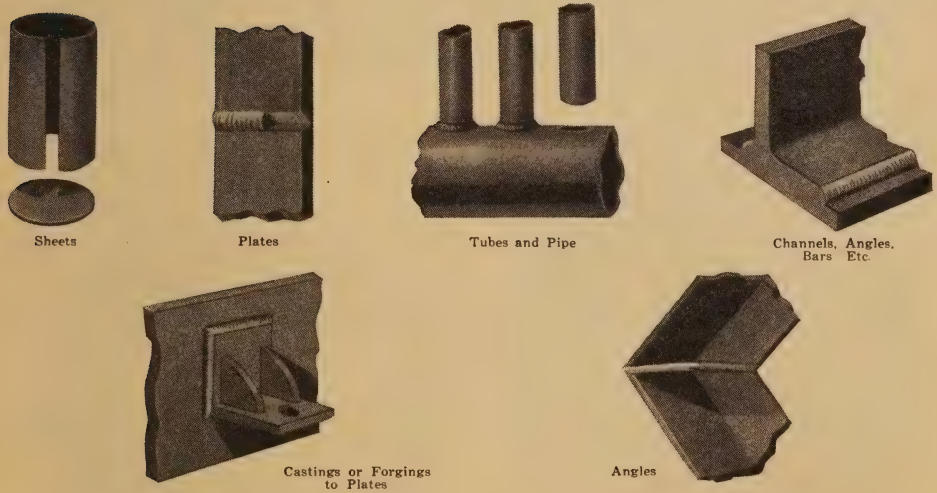


Fig. 90

Welding is the strongest method of joining steel parts and the least expensive.

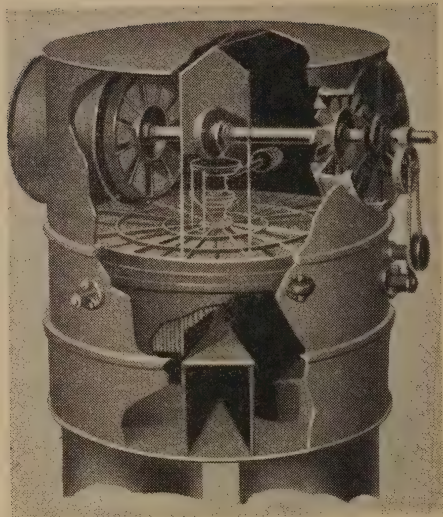
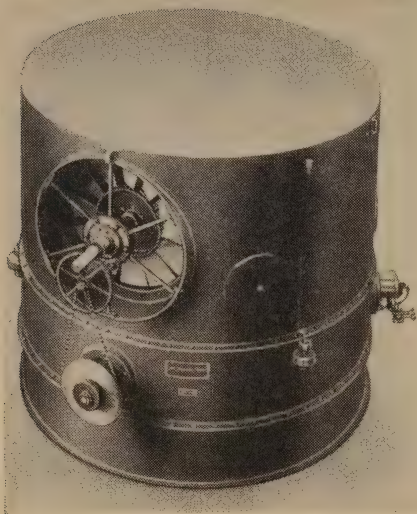


Fig. 91

The Ljungstrom Air Preheater, manufactured by The Air Preheater Corporation, Wellsville, N. Y., is a remarkable example of equipment designed to be produced by arc welding. This preheater is built in various sizes up to 18 feet in diameter and 21 feet high. Casting the moving parts would make them too heavy to function properly to say nothing of the prohibitive cost. Riveting would be too expensive and would likewise increase the weight unnecessarily. Arc welding is the only method by which this equipment can be economically manufactured.

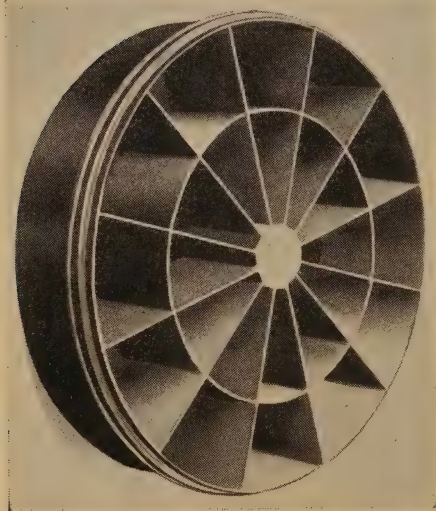


Fig. 92

The rotor of the Ljungstrom Air Preheater. All joints are arc welded. No other method of making this rotor would give light weight, low cost and necessary strength.



Fig. 93

Upper and lower section of housing for the Ljungstrom Air Preheater. Sections are bolted to facilitate shipping. All permanent joints are arc welded.

Replacing Castings by Arc-Welded Steel

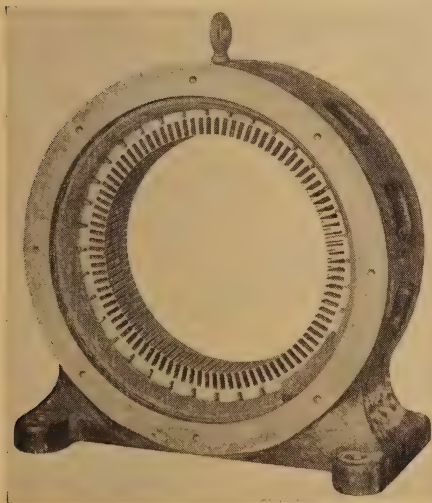
When redesigning a casting for arc welded steel:

First. Study the casting and determine definitely just what its function is in the machine and what requirements it must meet. When this is done it is a simple matter to decide whether or not a suggested change in form or shape is allowable.

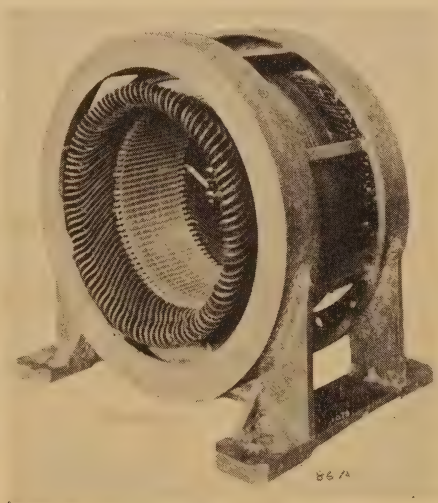
Second. Analyze the casting into its component parts and choose the standard steel shapes which will do the same job that the various parts of the casting are called upon to do. If the point of view is cultivated of looking at every casting as an assembly of parts rather than as a composite whole this analysis of shape comes naturally whenever a new casting presents itself.

Third. It sometimes occurs that all parts of a particular casting can be replaced by standard structural steel except some detail which is necessarily of peculiar shape. In this event, the rolling or bending fixture will take care of a very large percentage of these cases by changing the form of the standard steel shape to make it conform to the requirements of the design. The rolling of a standard angle into a circular ring is an example of this.

Fourth. There may still occur some details which do not seem susceptible to the rolling or bending processes. In such cases (which are very rare) recourse must be made to a cast or pressed steel part.



CAST IRON



ARC-WELDED STEEL

Fig. 94

The most intricate casting can be replaced by arc-welded steel.

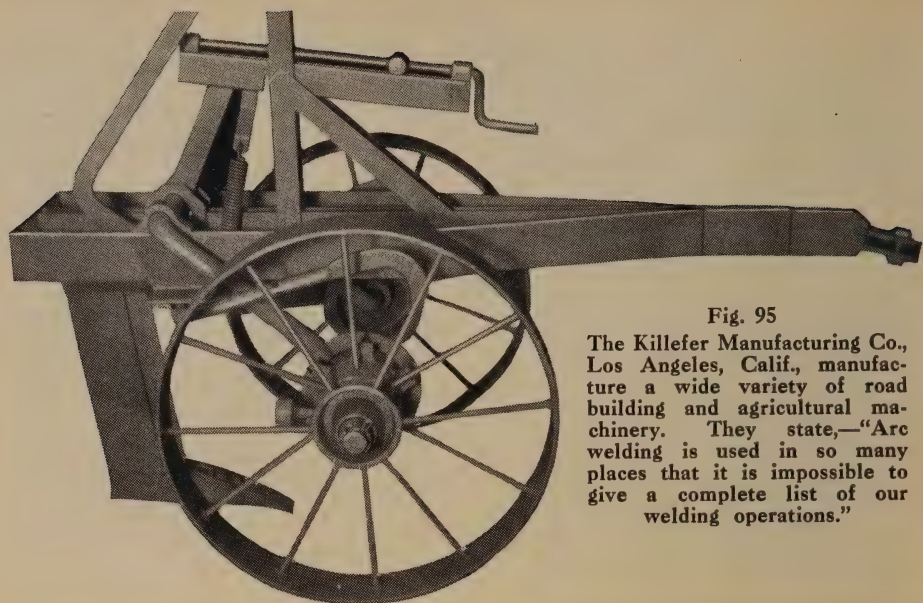


Fig. 95

The Killefer Manufacturing Co., Los Angeles, Calif., manufacture a wide variety of road building and agricultural machinery. They state,—“Arc welding is used in so many places that it is impossible to give a complete list of our welding operations.”

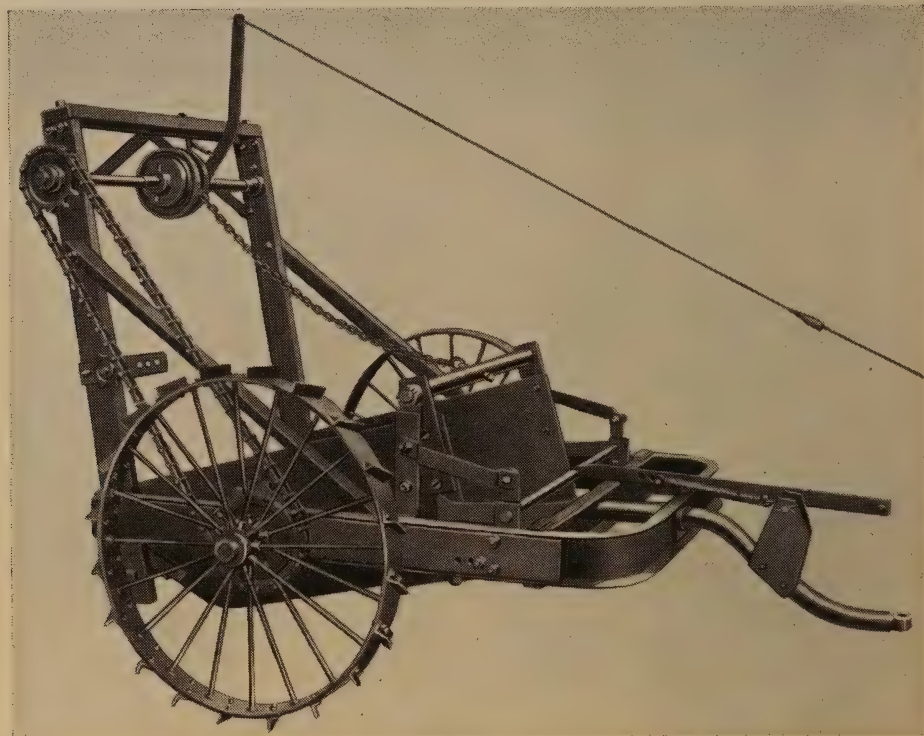


Fig. 96

Arc welding enables The Euclid Crane and Hoist Company, Euclid, Ohio, to sell this efficient scraper at an extremely low price. It is built for rigid service. All permanent joints are arc welded.

Redesigning the Entire Product

The range of products made from iron and steel is a vast one. To attempt to give detailed instructions on how to redesign every product for arc welding would be both presumptuous and futile. A detailed description of the method of redesigning a concrete mixer would not interest the builder of highway

bridges—yet in both of these products arc welding can be utilized to advantage. Only the fundamental principles of redesigning for arc welding fall within the scope of this book but it is believed that with a knowledge of these principles the designer will have no difficulty in applying them to his own product.



Fig. 97

There are two reasons why The Jaeger Machine Co., Columbus, O., use arc welding on this concrete mixer. One is to keep the cost down, because the market is highly competitive. The other is to give this mixer the husky strength to stand up under the service expected of Jaeger equipment.

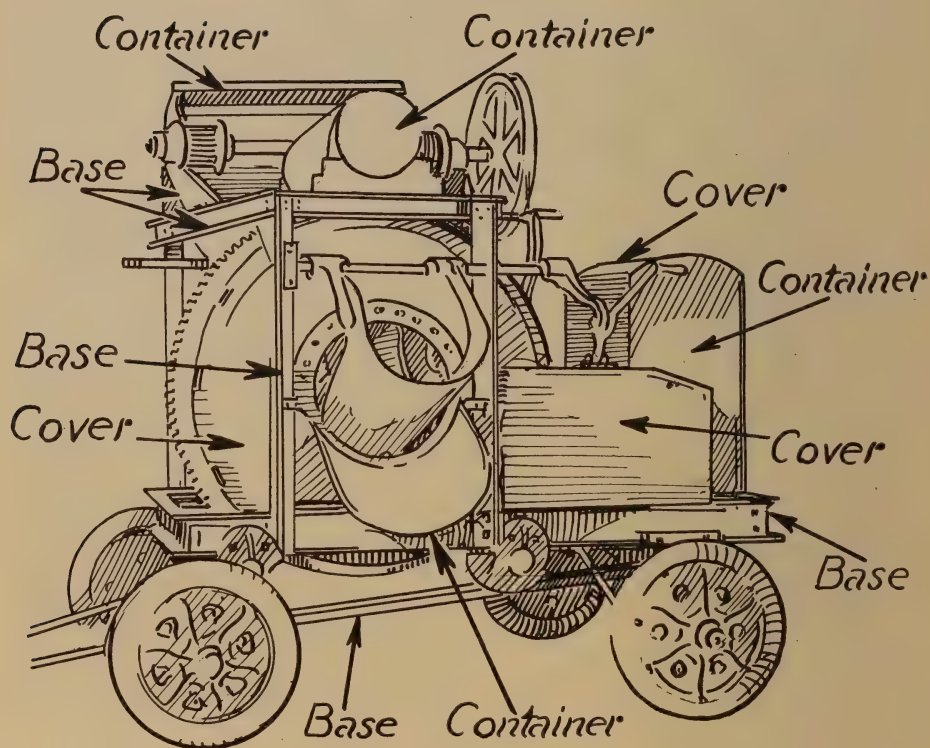
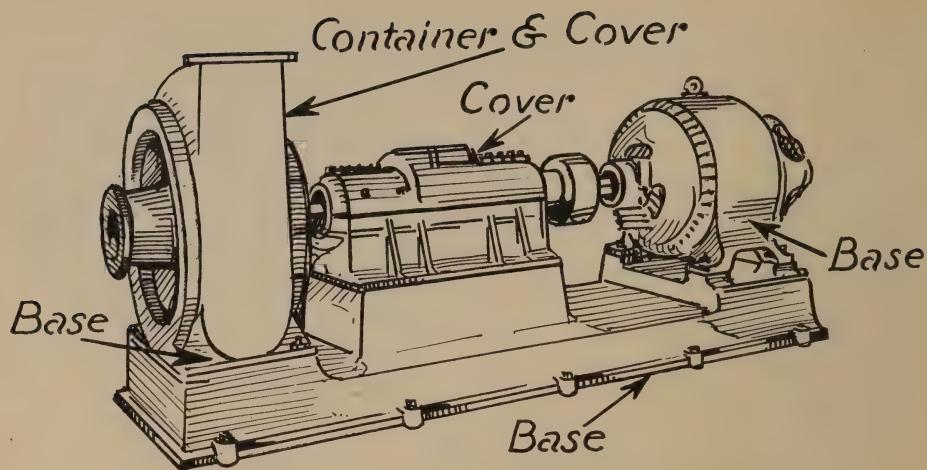


Fig. 98

The structural parts of every machine may be classed as either bases, covers or containers.

Bases, Covers and Containers

Notwithstanding the diversity of products manufactured from iron and steel, there are still some characteristics which are common to all. It will be found upon careful analysis that every structural part of any machine, structure, or piece of equipment can be classified in one or more of these three classifications—bases, covers, and containers. It may be a new conception to think of all structural machine parts as being so simply classified, but a little thought will show that this is true. Some parts may fall in both classifications. A worm gear housing, for instance, may be classed both as a base and as a container if it serves to support, as well as enclose, the moving parts. This, however, does not make the classification any less

valuable for the purpose of this discussion.

Figure 98 shows two widely different pieces of equipment with the various parts labeled in accordance with this classification.

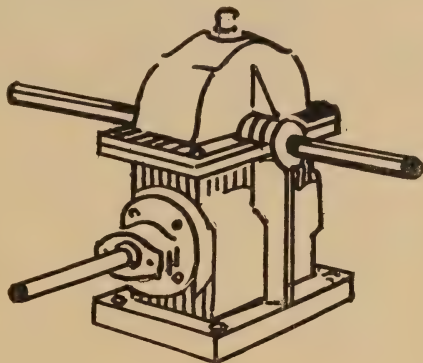


Fig. 99

In this Worm Gear Housing the Base is also a container.

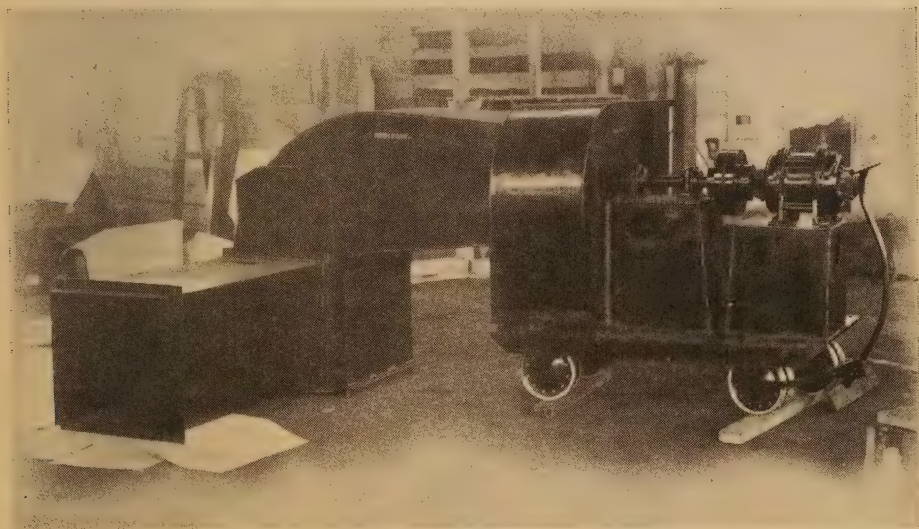


Fig. 100

Manufacturers of fans and blowers have been among the first to redesign for arc welding. Steel has replaced cast iron throughout in the construction of these models built by the Robinson Ventilating Co., Pittsburgh, Pa.

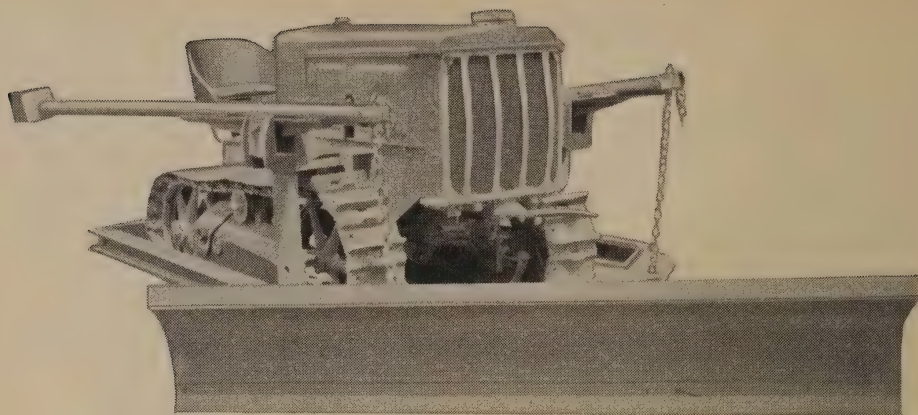


Fig. 101
Backfiller manufactured by The Killefer Manufacturing Company, Los Angeles, Calif. The rocker arms on this machine are made by arc welding extra-heavy pipe to a steel casting. This company arc welds all kinds of agricultural machinery.

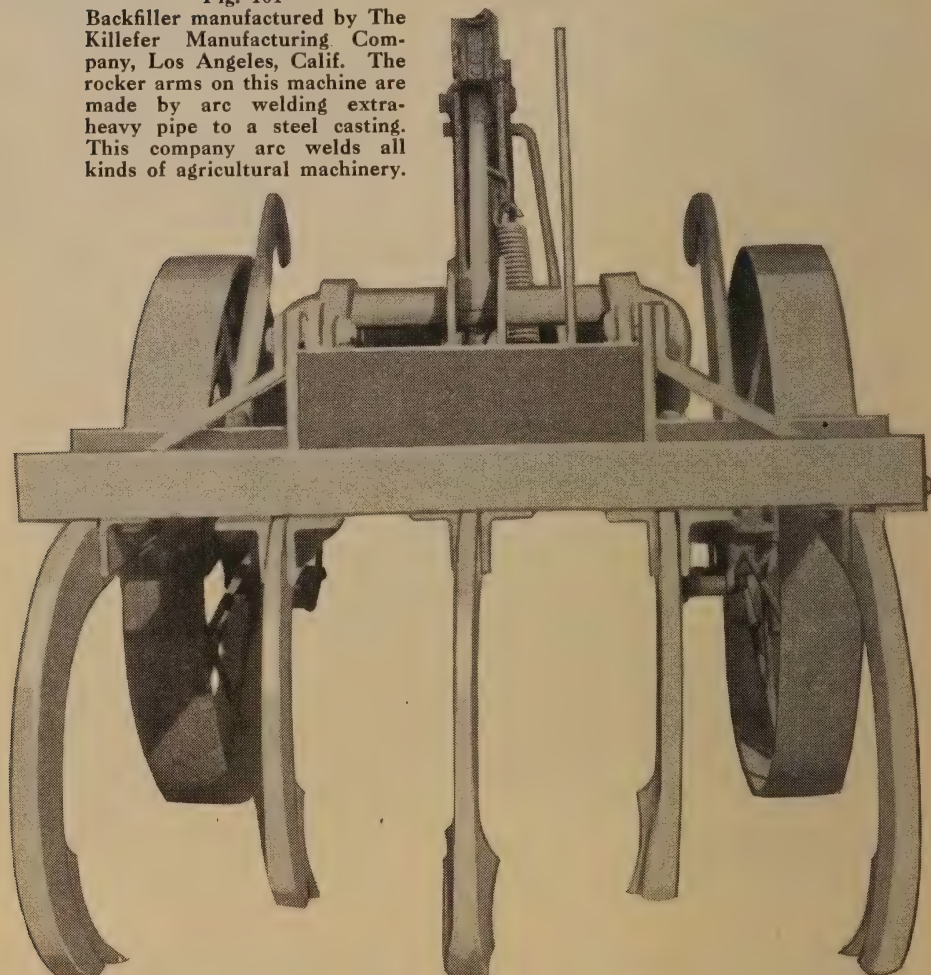


Fig. 102

Any Base Can Be Built of Arc Welded Steel

The term *base*, as used here, is intended to embrace every part whose chief function is to support. It includes:

- Brackets, Beds, Legs.
- Superstructures.
- Outboard bearings, Pedestals.
- Arms, Goosenecks, End Brackets.
- Bearing boxes, etc.

At present, by far the majority of bases are made of cast iron. Riveted steel is also used, but this discussion has to do chiefly with re-designing cast iron bases on the assumption that where riveted steel

is now used the application of arc welding is obvious.

Fortunately, redesigning for arc welding is a comparatively simple matter. It is much less difficult to design a machine base of arc welded steel than to design the same base in cast iron.

It is not necessary to allow for casting shrinkage, draft on patterns, cores or fillets. The designer works directly for the ultimate result, unhampered by limitations of the casting process which make it impossible to cast the most efficient sections.

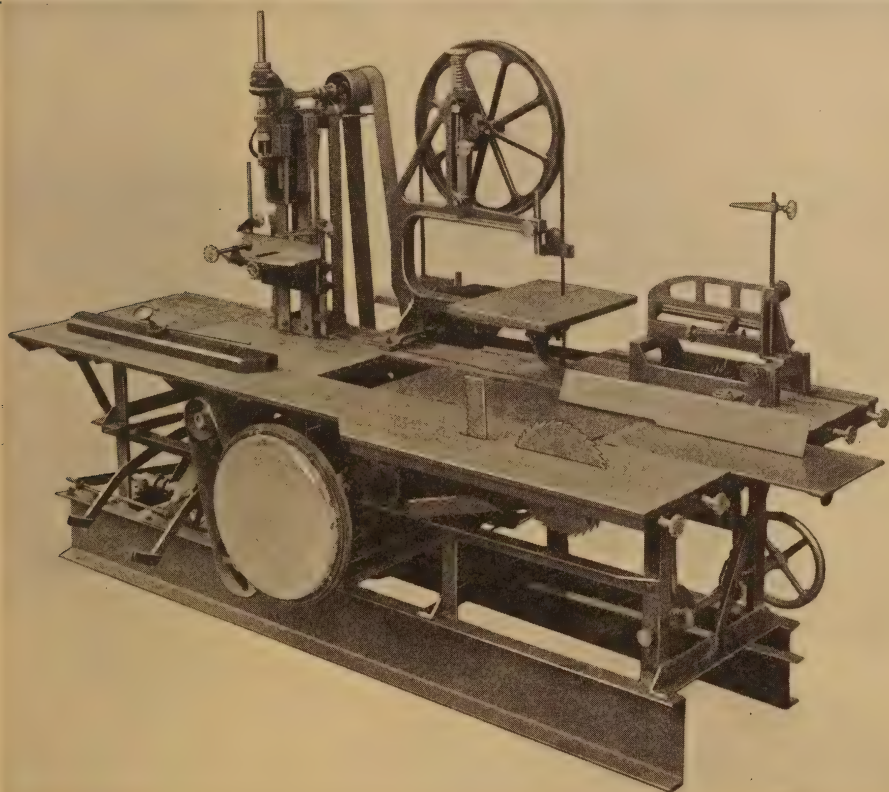


Fig. 103

A fine example of light, strong and economical construction for machinery bases. This machine and many others manufactured by The Parks Ball Bearing Machine Company, Cincinnati, O., are arc welded throughout.

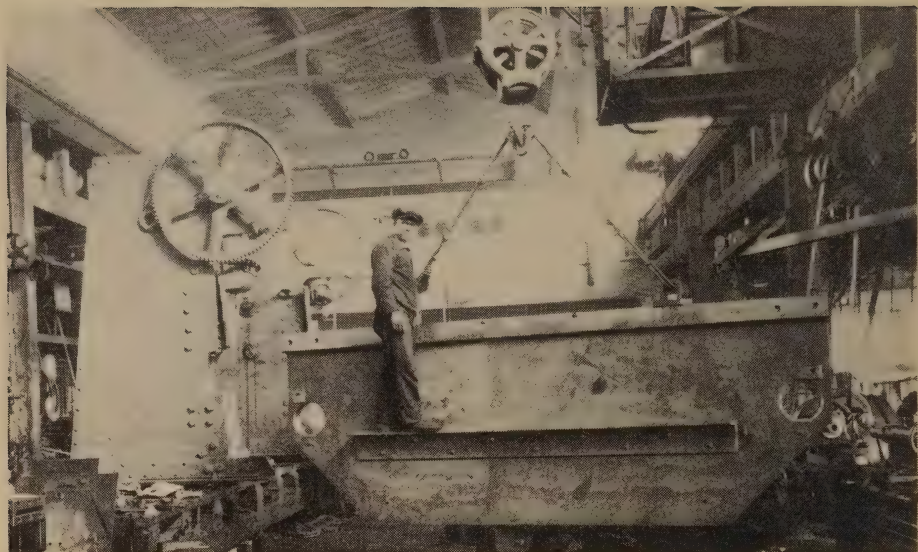


Fig. 104

Assembling the 300-ton press brake illustrated below. This picture gives an idea of the size of this huge machine. Steel is superseding cast iron in the manufacture of machine tools where great strength is required.

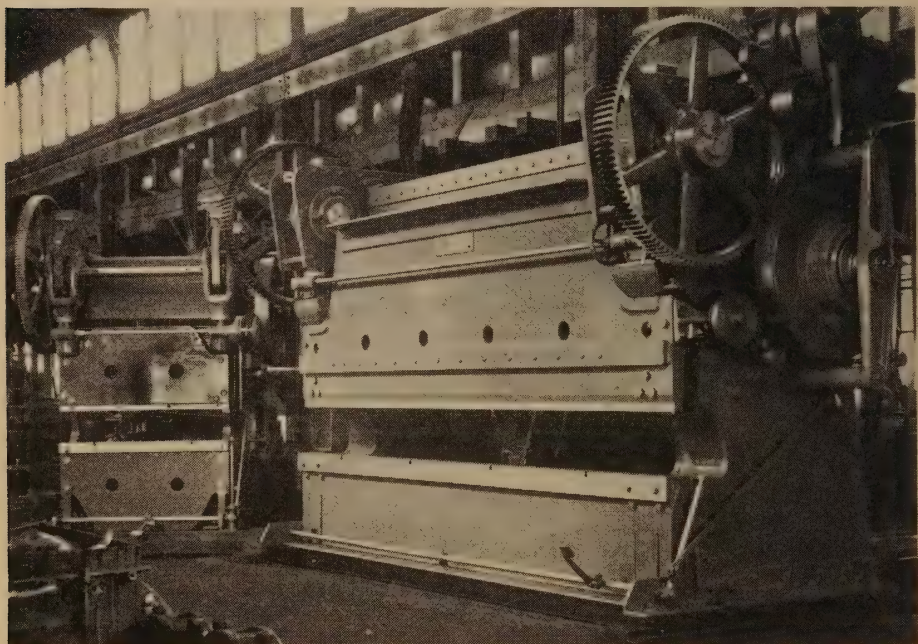


Fig. 105

300-Ton Press Brake manufactured by the Cincinnati Shaper Co., Cincinnati, Ohio. This machine is 11 feet 9 inches high. Note how rolled steel has replaced cast iron. Arc welding is employed to give this machine its extreme rigidity.

First, analyze the purpose of every part of the base. Then determine the stress to which every part is subjected. It is usually a simple matter to determine whether a member is in tension or compression. If it is subjected to both stresses, the designer can usually tell which stress is the more important. He can also determine with sufficient accuracy, the amount of the stress, which, of course, governs the size of the members. This is fundamental to all designs, whether the base is to be made of cast iron, riveted steel or arc welded steel.

The next step is simply to select the standard steel shapes which will best meet the above conditions. Join the standard steel shapes by arc welding with the assurance that the joints will be as strong as the members joined. The entire base will be an integral piece of steel—lighter in weight, stronger and less expensive to manufacture. Since steel is stronger than cast iron the various parts of the base can be made smaller. This may change the appearance of the base somewhat but will in no way interfere with its utility.

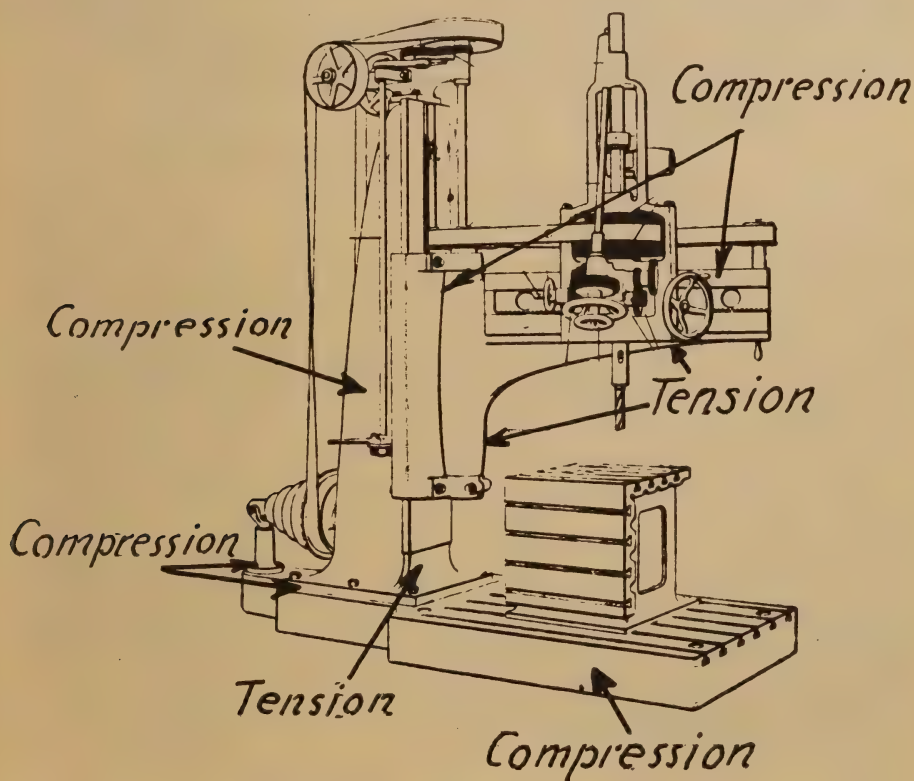


Fig. 106

Every structural part of any machine is subjected to either tension or compression or bending.



Fig. 107

Special-purpose trucks of all descriptions can be made quickly and cheaply by arc welding. Here is one that was built to facilitate unloading steel shapes.

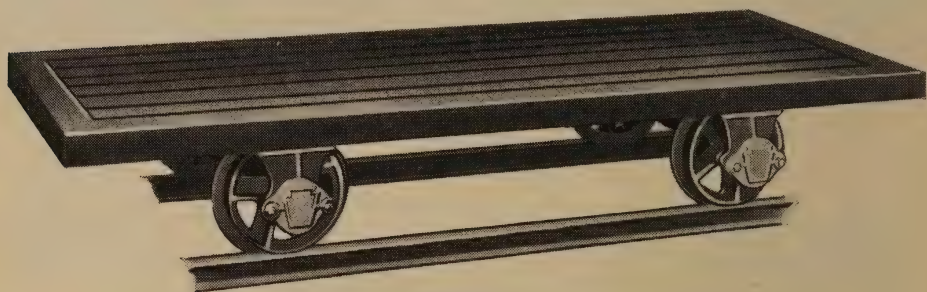


Fig. 108

The frames of these dryer cars are made of 3"x3"x1/4" steel angles bent around a form and arc welded, making a solid, rigid one-piece frame. These cars are manufactured by The Hadfield-Penfield Steel Company, Bucyrus, Ohio.

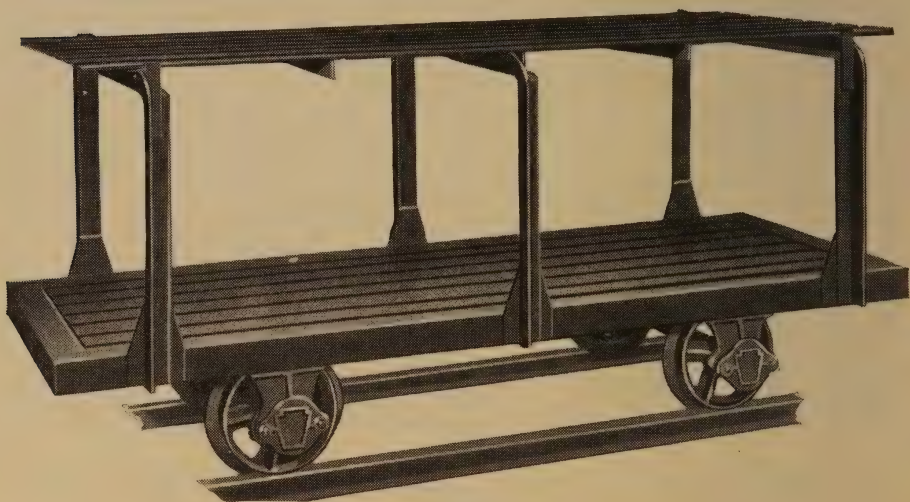


Fig. 109

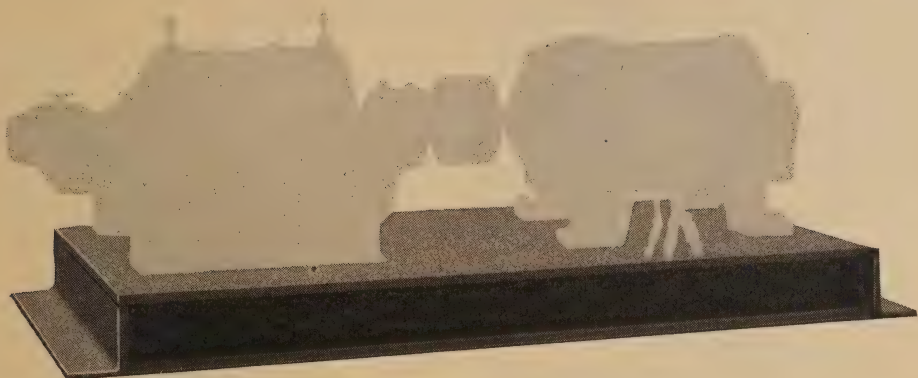


Fig. 110
Base for direct connected motor driven machine.

In this manual are illustrated many different styles of bases which were built on this principle. It is not feasible to describe them all and in most cases the pictures themselves are self explanatory.

In figure 110 is a simple example. This type of base is suitable for any direct connected motor-driven unit such as a pump, a crusher, a generator, elevator engine, etc. As the illustration shows it is made entirely from standard steel shapes.

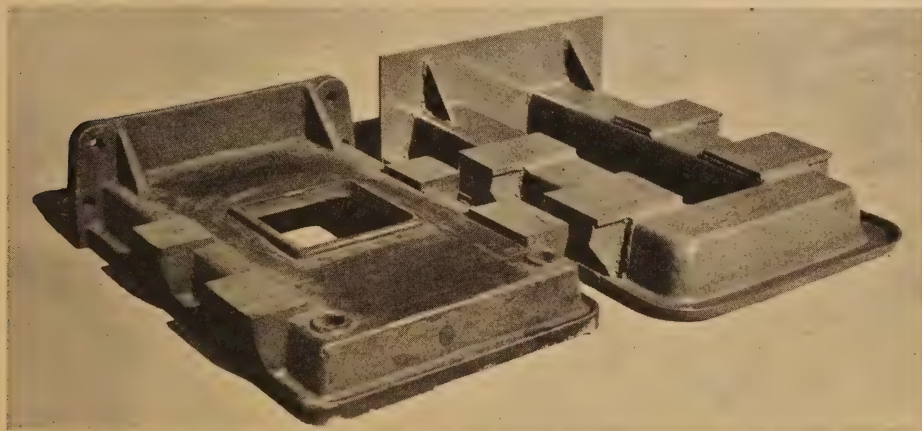


Fig. 111
Elevator base redesigned for arc welding by the Houghton Elevator Company, Toledo, Ohio. The cost figures are convincing.

	Weight	Cost
Cast Iron	184 lbs.	\$11.04
Arc Welded Steel.....	109 lbs.	5.45

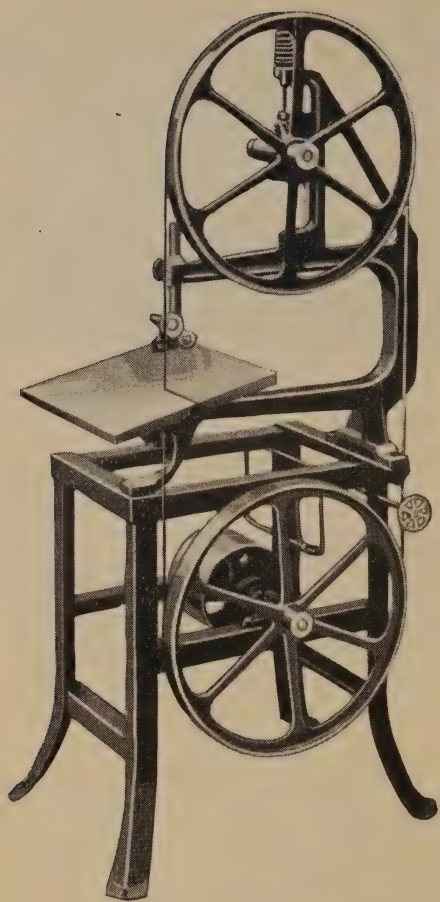
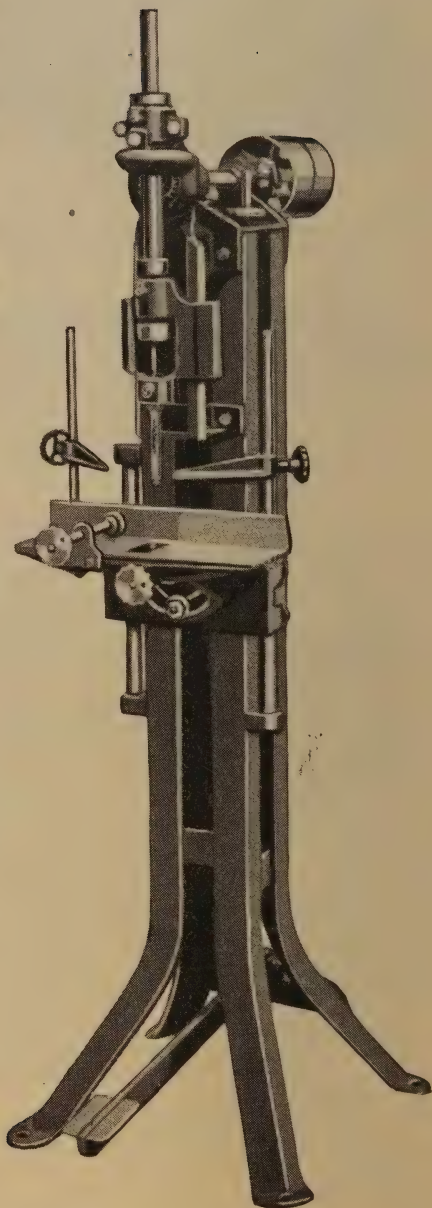


Fig. 112

Arc-welded bases need not be awkward. While the bases for these machines look different from the traditional cast-iron bases, they are graceful and workmanlike. They are also cheaper than cast iron and stronger.



Typical Base for Floor Grinder

Another example is a base for a machine such as a floor grinder, a polishing wheel or an arbor press. The machine base in this case is simply a support to bring the working parts to a convenient height. Of course, the base must be reasonably rigid to avoid undue vibration.

To make a base of this nature of welded steel, a standard I-beam serves as the column support. Two

flat plates welded on the foot of the I-beam provide the large floor bearing. Welded braces made from steel plates give the necessary stiffness and another flat plate forms the bed for the working parts. The entire base can be built before the pattern shop could lay out the core box for a cast iron base and at a fraction of the cost.

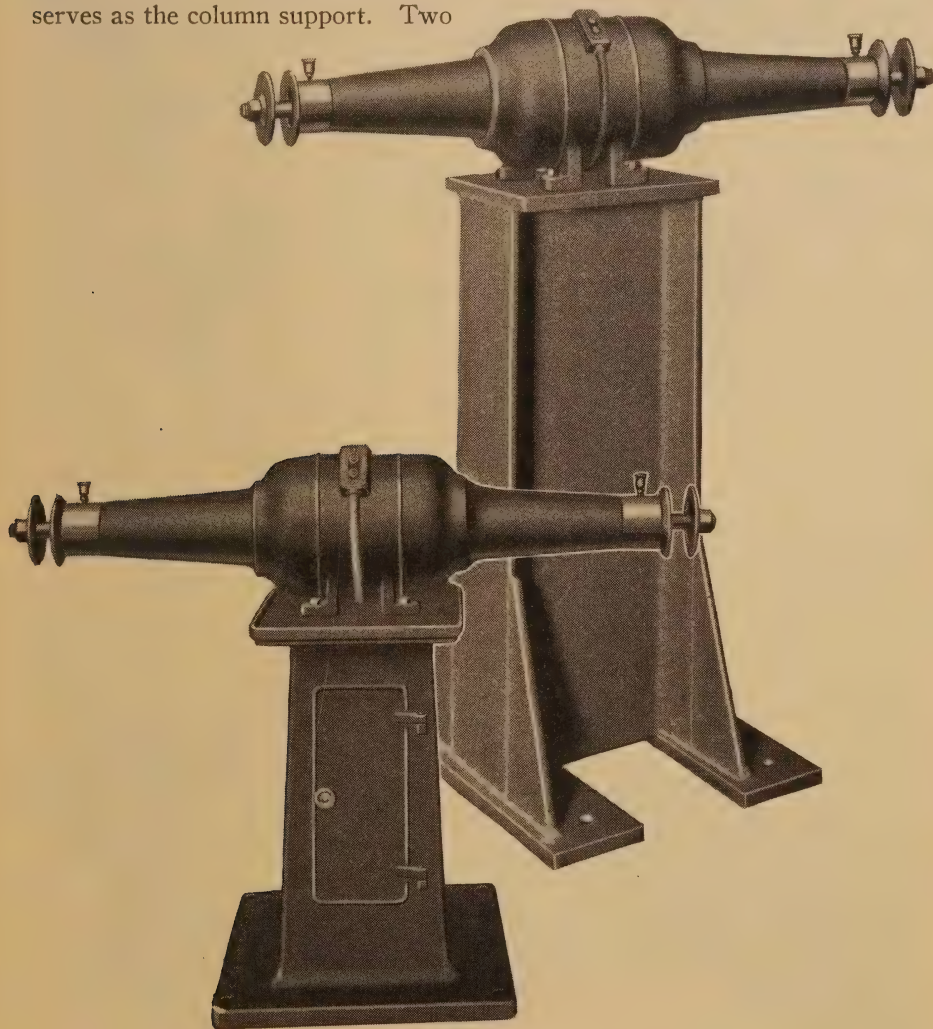


Fig. 113

The welded steel base is more rigid than the cast iron base costs less and requires practically no machining.

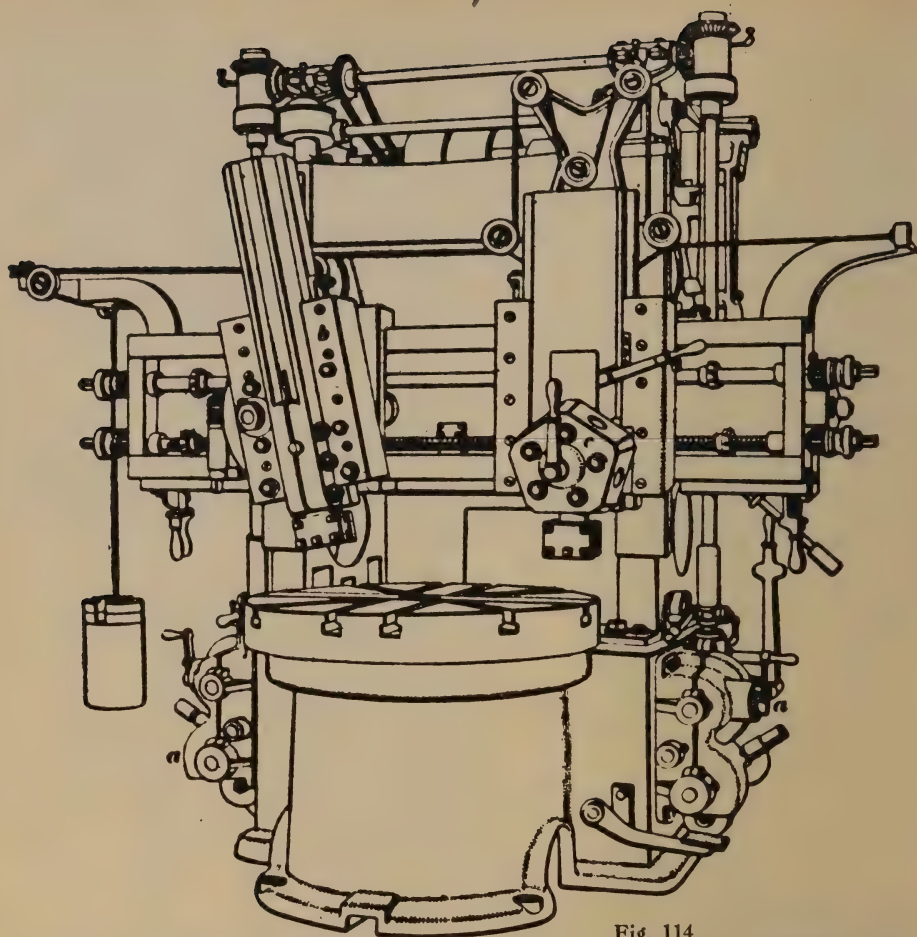


Fig. 114

Boring mill bases have always been made of cast iron. Below is a similar base of arc-welded steel.

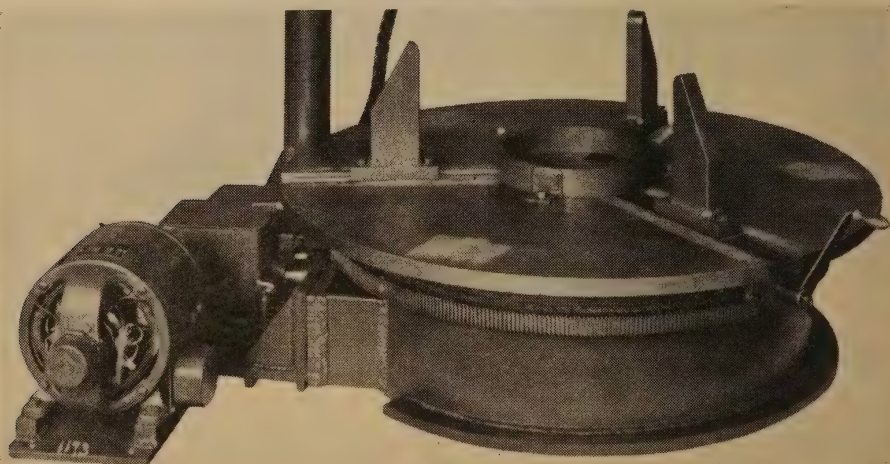


Fig. 115

An All Steel Lathe

Examples might be multiplied, but the truth is apparent that the sole purpose of any base is to support the moving parts, whether the machine is a grinder, a concrete mixer, or a portable coal loader. The best base is the one which has the necessary strength and rigidity and which can be built at the lowest cost.

Let us consider another example of a machine which has heretofore been made of cast iron, namely an ordinary engine lathe. A lathe consists fundamentally of four parts—a bed, a headstock carrying the driving mechanism, a carriage which slides along the ways on the bed, and a tailstock. The purpose of the bed is simply to support the moving parts and keep them in alignment. It is extremely important that the bed be sufficiently rigid so that it will not deflect under the pressure exerted against the lathe tool. In other words, the greatest stress is a bending stress.

Since cast iron is weak in flexure, lathe beds are built with a very deep web to provide the necessary rigidity. In order to draw the bed pattern from the sand in the foundry, the shape of the casting must be made radically different from the shape which would withstand the greatest bending stress. This is one

of the limitations of the casting process.

Now suppose this lathe bed to be made of welded steel. Since it is called upon to withstand a bending stress, the steel section best suited for this purpose is chosen, that is, the standard I-beam.

Instead of the heavy cast iron base, two I-beams would be solidly joined together by arc welded cross braces.

The legs would be made of either I-beams, standard channels or angles depending on the design.

Hardened steel ways screwed to the tops of the I-beams would replace the cast iron ways, providing a simple means for renewal when badly worn.

Because of the greater strength of steel and because the most efficient sections can be used, a welded steel lathe would be stronger, lighter and cheaper than a cast iron lathe. Obviously it would not look the same. Its first appearance would doubtless cause smiles from users accustomed to the flowing curves and deep fillets of cast iron construction.

Fillets and curves, however, are but evidences of the limitations of cast iron and it will be only a short time before steel bases are accepted as standard on most machine tools.

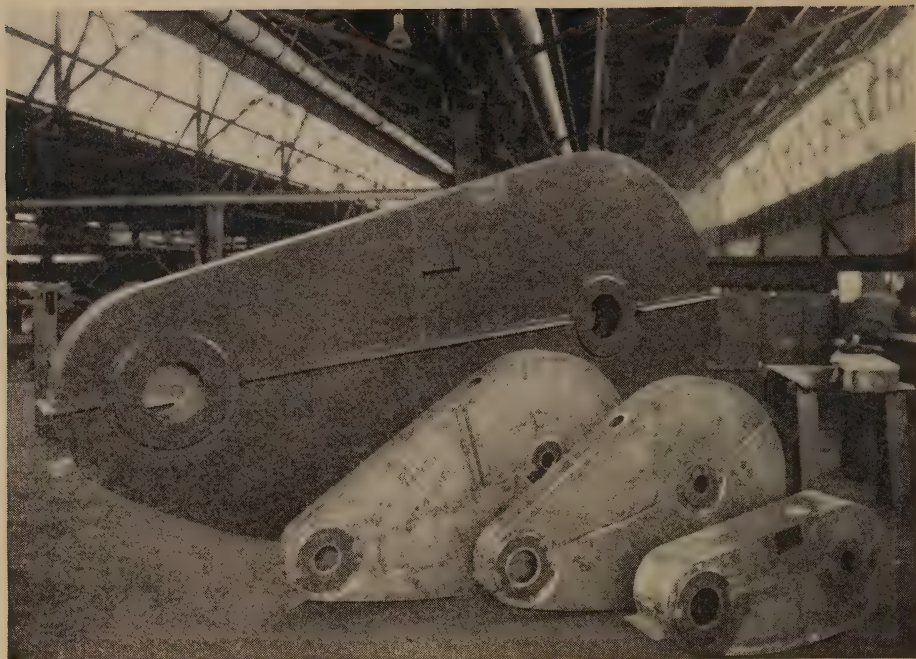


Fig. 116

Gear Guards of every size and description are arc welded by the Link-Belt Company, Philadelphia, Pa.

Make All Covers of Arc Welded Steel

The term *covers*, in this classification, is intended to include:

Gear guards.

Doors.

Pulley housings.

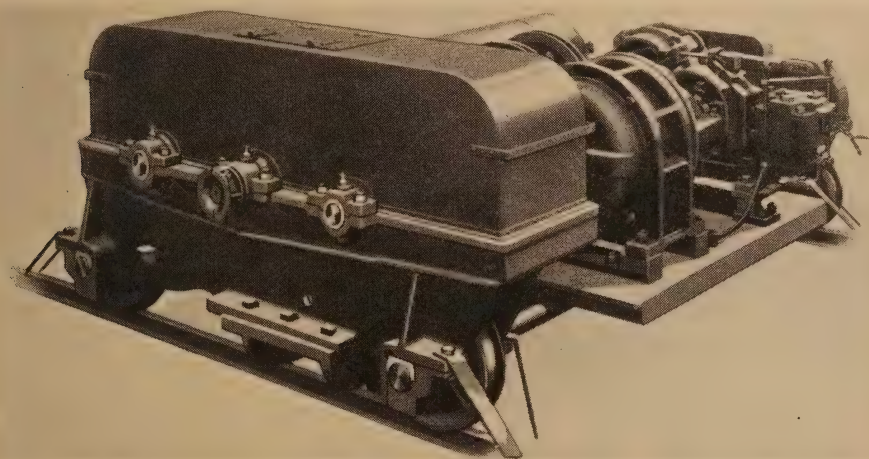
Dust covers.

Lids for oil wells, etc.

The purpose of covers on any machine is either to protect the internal mechanism from damage from the outside or to shield the moving parts so that they them-

selves will not be a source of danger. Usually covers are not subjected to any considerable stress, and consequently the lightest cover is the best cover provided it has the requisite stiffness.

Gear guards probably are the widest used form of covers. The former method of making these was either by casting or by riveting steel. Cast gear guards have all the disadvantages of any cast-iron prod-



The gears on these overhead crane trolleys are enclosed in guards of arc-welded steel. This is one of the many applications made by the Whiting Corp., Harvey, Ill.

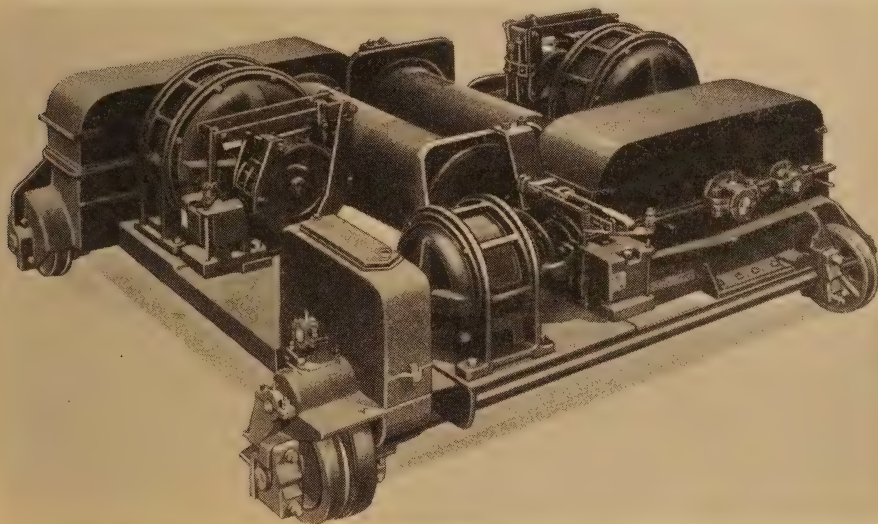


Fig. 117

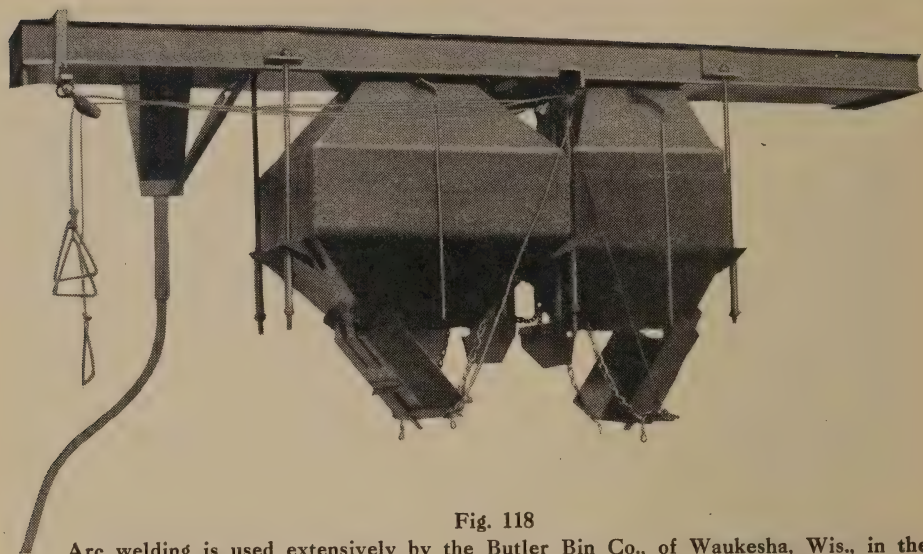


Fig. 118

Arc welding is used extensively by the Butler Bin Co., of Waukesha, Wis., in the manufacture of their batch measuring hoppers and other products.

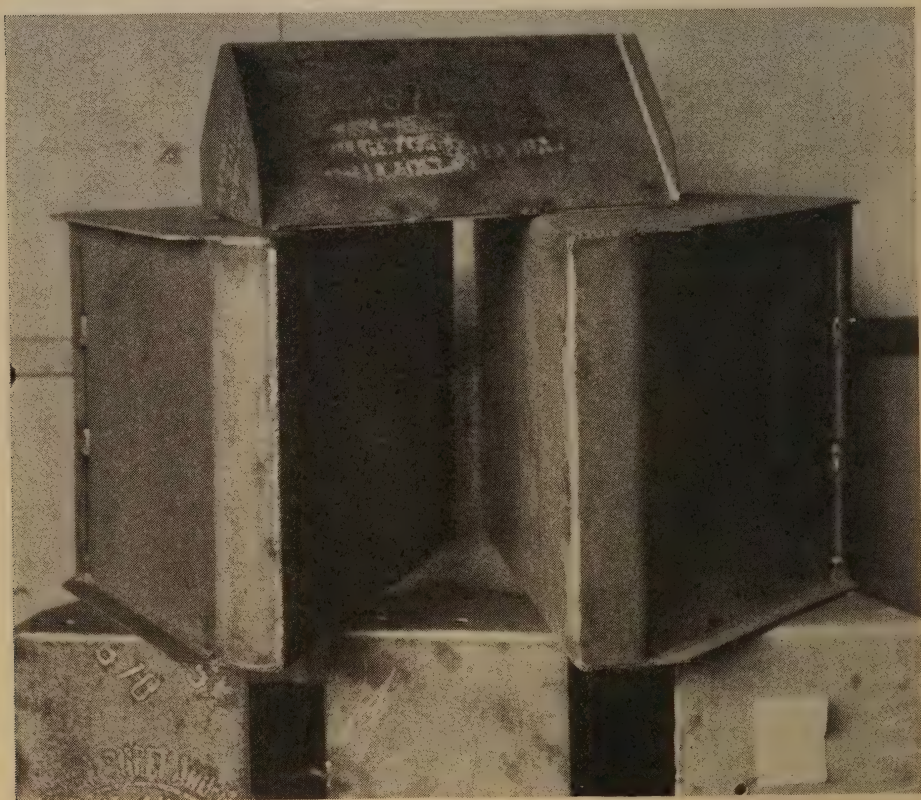


Fig. 119

Conveyor buckets arc-welded by The Link-Belt Company, Philadelphia, Pa.

uct which include high cost and unnecessary weight. Riveted gear guards, while utilizing less expensive steel, require flanging or flange angles, so that the cost to manufacture is often higher than that of a casting. Furthermore, the rivets have a tendency to work loose under the constant vibration to which gear guards are subjected.

The construction of arc-welded gear guards is simplicity itself. Sheet or plate is cut to the proper shape and the edges welded so that the entire part is an integral piece of steel. Gear guards of this nature may be made dust tight and oil tight and the cost is a fraction of that for other methods.

Covers other than gear guards can be made in the same manner. Use standard steel sheet or plate

form if necessary and weld all joints.

An example of a cover known to everyone is a door such as is used on a milling machine and very frequently on other machine tools. This door carries no part of the load on the machine, and is only subject to breakage through being struck. However, because cast iron is extremely brittle in thin sections, doors are cast in sections many times heavier than would be required if steel were substituted.

Doors of this nature can be easily made from flat stock stiffened where necessary by welding on ribs or angles. Hinges and knobs can likewise be welded on and the cost would be less than for any other style of construction.

The cylinder, gear guards and many other parts of the Henrici washer are arc welded. This is one of large numbers of models built by the Henrici Laundry Machinery Co., Boston, Mass.

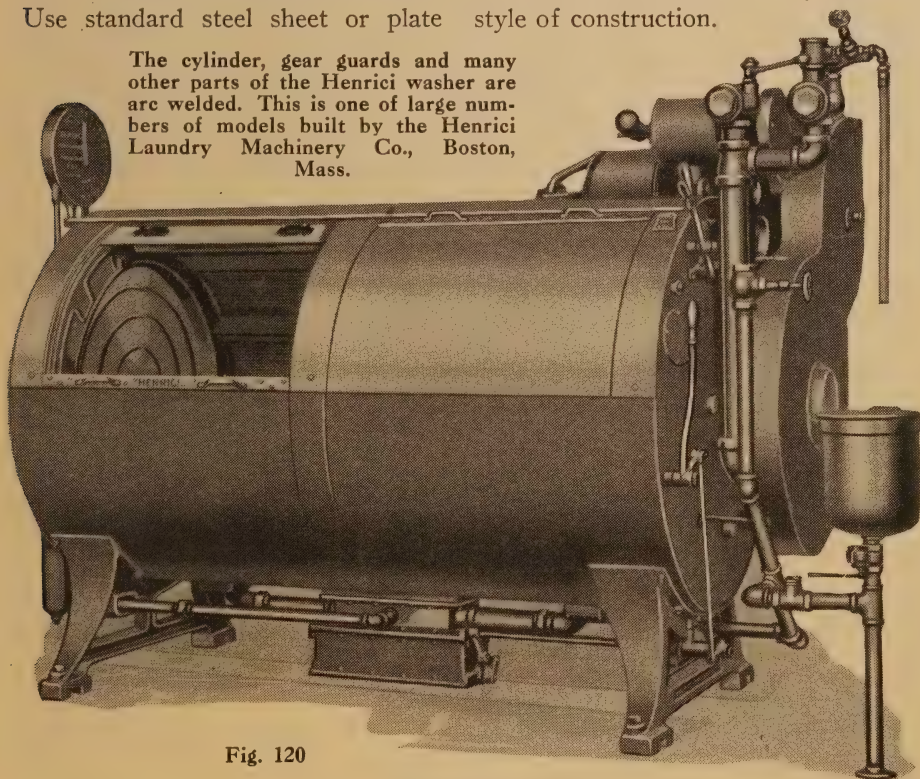


Fig. 120

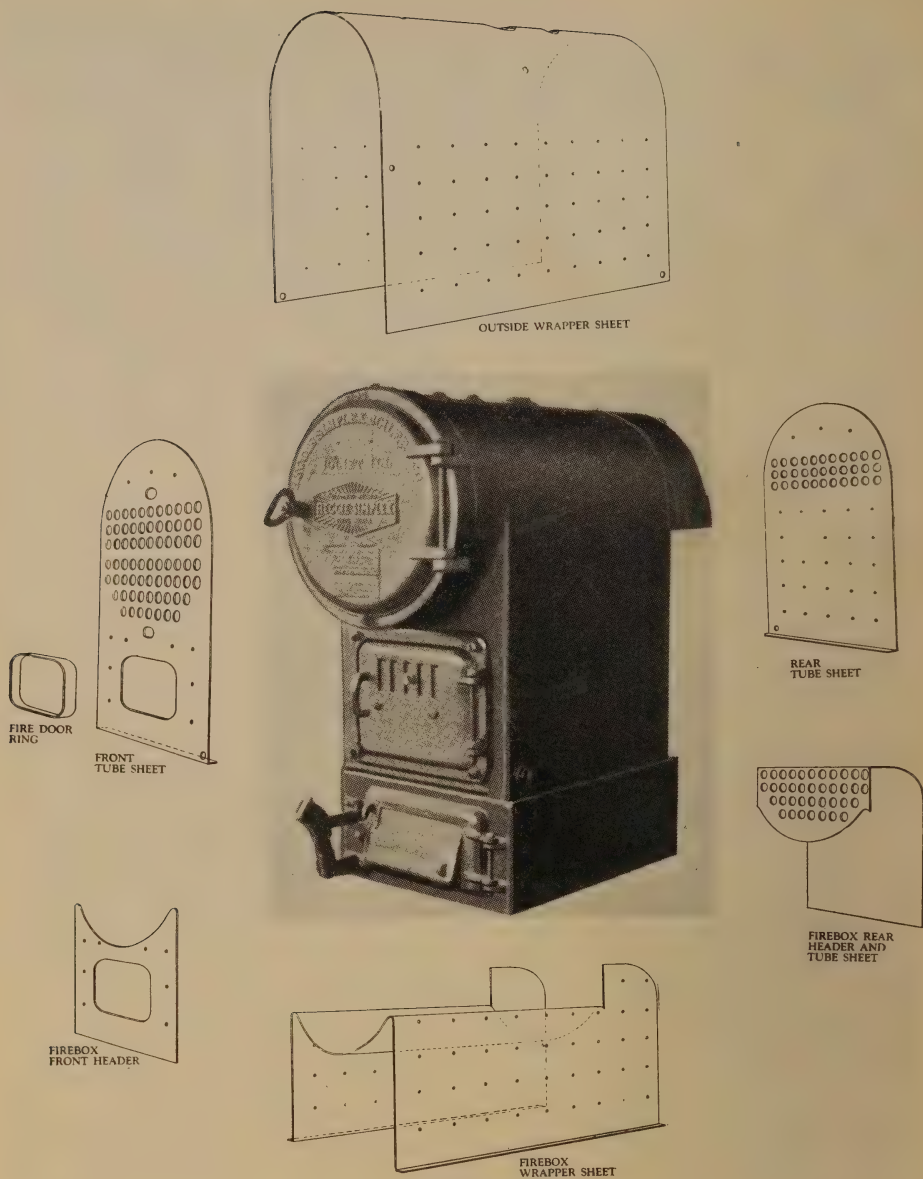


Fig. 121

All seams of this heating boiler are arc welded. Note the simplicity of construction. Only seven steel plates are used. The Heggie-Simplex Co., Joliet, Ill., manufacturers of this boiler, arc-welded all of their various models.

Arc Weld All Containers

The classification *containers* is extremely broad and includes:

Tanks of every description.

Boilers.

Hoppers.

Drums.

Bins.

Chutes.

Mixing chambers.

Tumbling barrels.

Vats.

Revolving driers.

Dump cars.

Clamshell buckets.

Annealing pots, etc.

Tanks will be considered first because their use is more general than any of the other items in this classification.

The first requisite of a tank is that it be tight. It must also have sufficient strength to withstand the internal pressure to which it may be subjected. In pressure tanks the plates and joints are in tension. In riveted construction, which was formerly the only method of making pressure tanks, the strength in tension of a riveted joint is always less than the strength of the plates joined. This is because the plates are weakened at the joint by the rivet holes. To obtain the necessary strength it is therefore necessary to provide for this weakness at the joints. Since the efficiency of the usual riveted joint varies from 45%



Fig. 122

Arc-welding is the approved method of making tank trucks for transporting inflammable liquids. This one was built by the A. F. Robinson Boiler Works, Boston, Mass. There are no rivets to work loose and start leaks.



Fig. 123

Arc-welded water tanks are superseding riveted tanks because they do not require periodic recaulking. This one was built by The Leitelt Iron Work, Grand Rapids, Mich.

to 75%, the increase in the thickness of the plates to provide for this is considerable and represents a large part of the cost of any tank.

In arc-welded construction the joints can be made as strong as the plates joined. It is not necessary to make the plates thicker throughout their length to provide for the requisite strength at the joint. The plates are no more apt to fail there than at any other point.

Here, then, is one great saving by using arc welding in place of riveting. Furthermore, the actual cost

of making the welded joint is less than that for making a riveted joint.

In tank work there is still another advantage. In riveted tanks the method of making tight joints is by peening the metal along the edge of the plates into the joint by means of a caulking tool. This method is a makeshift at best and is also expensive. It is frequently necessary to recaulk after the tank has been in service a short time. Arc welded tanks are tight because the plates are solidly joined, making the tank actually a single piece of steel. In addition, a welded tank resists corrosion better than a riveted tank, and avoids leaks around rusted rivets.

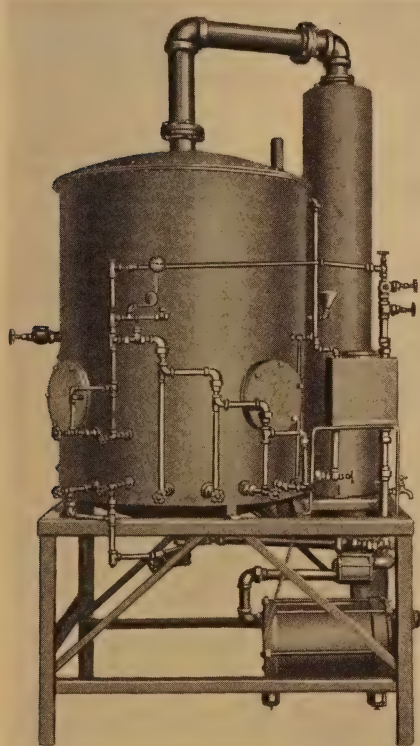


Fig. 124

This Bousman Still is used for reclaiming gasoline and other solvents used for dry cleaning. The Bousman Manufacturing Co., Inc., Grand Rapids, Mich., have found that arc-welded stills cost less and last longer than riveted stills.

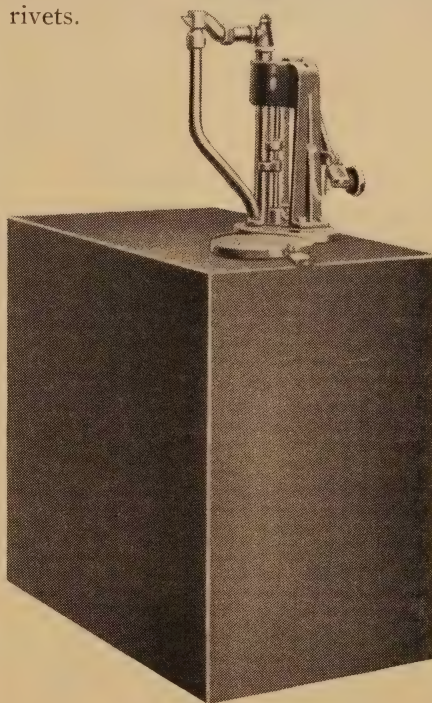


Fig. 125

No one wants a leaky gasoline or oil tank. That's why the S. F. Bowser & Co., Inc., Fort Wayne, Ind., arc welds the seams of this tank and many other styles of dispensing tanks. An arc-welded seam forever eliminates caulking.

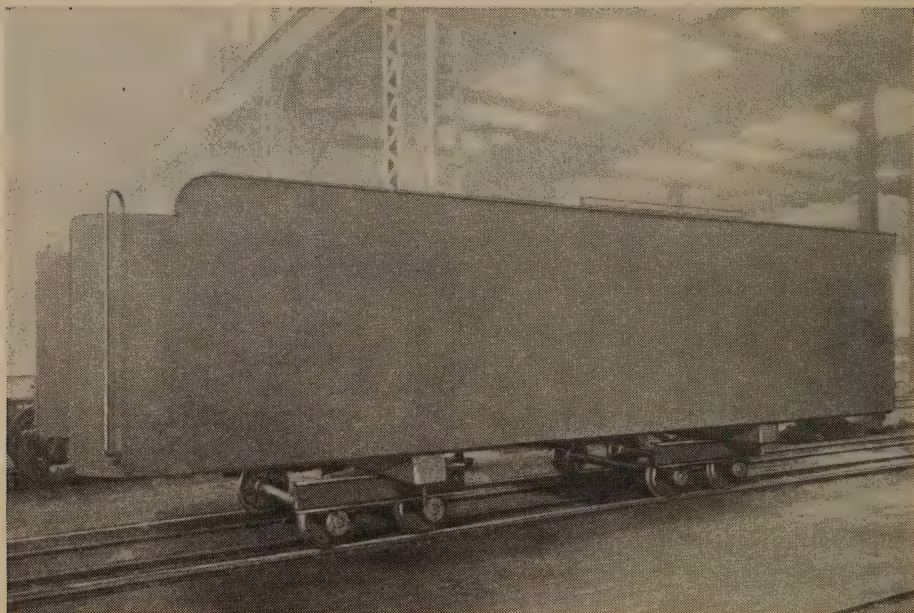


Fig. 126

Locomotive tender built by the Baldwin Locomotive Works, Philadelphia, Pa. Arc-welding has replaced riveting throughout. An arc-welded joint withstands vibration better than a riveted joint.

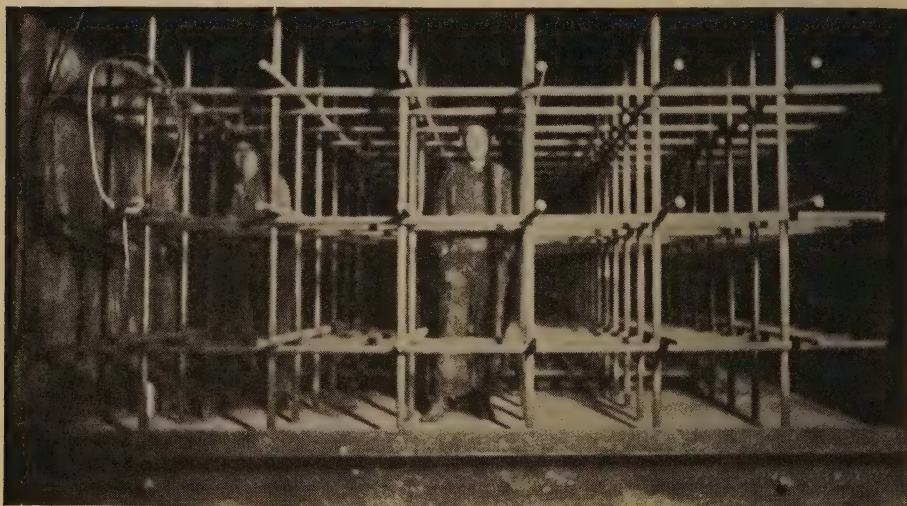


Fig. 127

The interior of a large fuel oil storage tank built in accordance with the New York City Building Code. This tank is stayed with $1\frac{1}{2}$ " steel rods on 24" centers. Stays and plates are completely arc welded. The Lancaster Iron Works, Lancaster, Pa., has made these tanks for the Equitable Life Building, Federal Reserve Bank, Waldorf Astoria Hotel, Astor Hotel, Belmont Hotel and others.

In making tanks by arc welding, the plates may be joined by butt welding, by single lap welding or by double lap welding. The butt weld has the advantage of great strength and also saves material. The cost of fitting and scarfing the plates, however, often offsets the saving in material. Where the tank is used for storage purposes and is not subjected to high pressure, the single lap welded joint may be used. For pressure tanks the double lap weld is recommended as this joint is as strong as the plates used.

Various methods of welding the heads in tanks are illustrated in

figure 138. Very large tanks may be strengthened by stay rods, welded at all intersections as illustrated in figure 127.

Containers other than tanks can also be made by arc welding cheaper than by riveting or casting. Examples, including conveyor buckets, concrete mixing drums, compensator housings, and many others, are illustrated in this manual. The designer will have no difficulty in seeing how arc welding is utilized in making these and will doubtless find many suggestions which he can apply to his own problems.

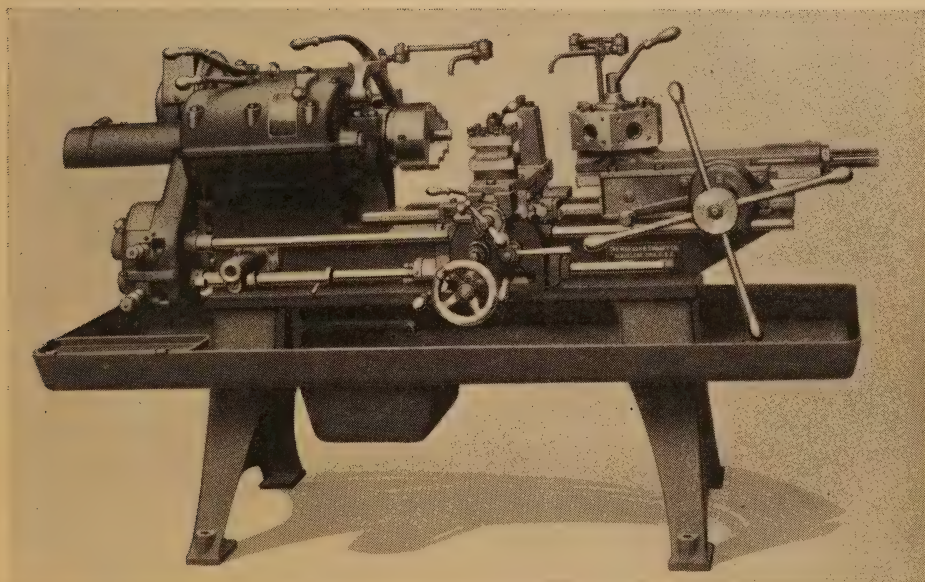
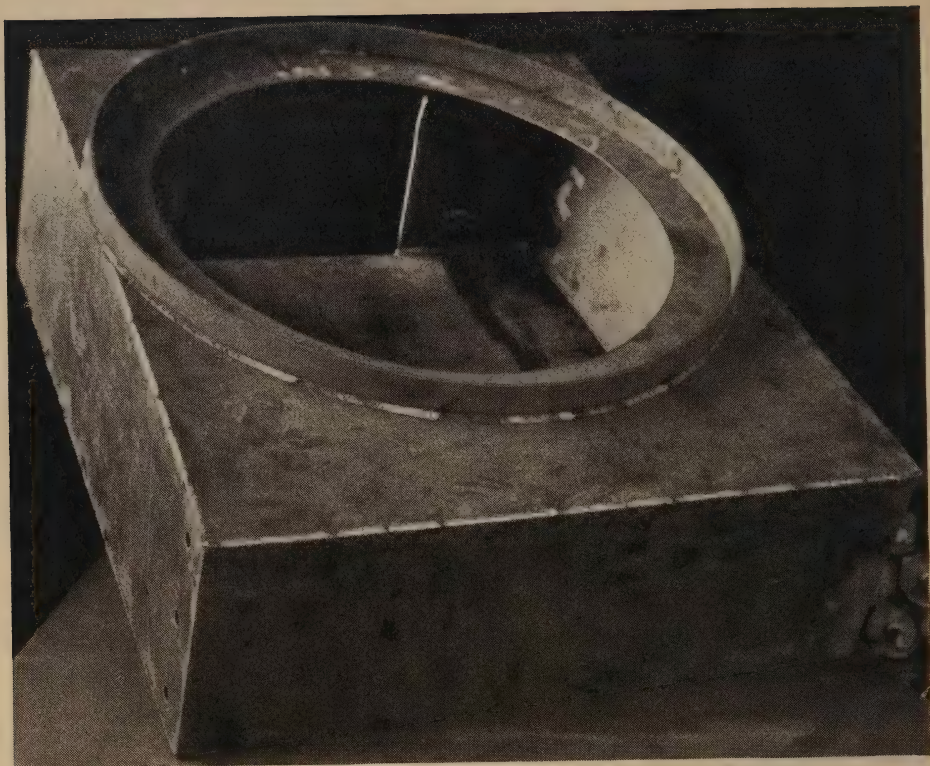
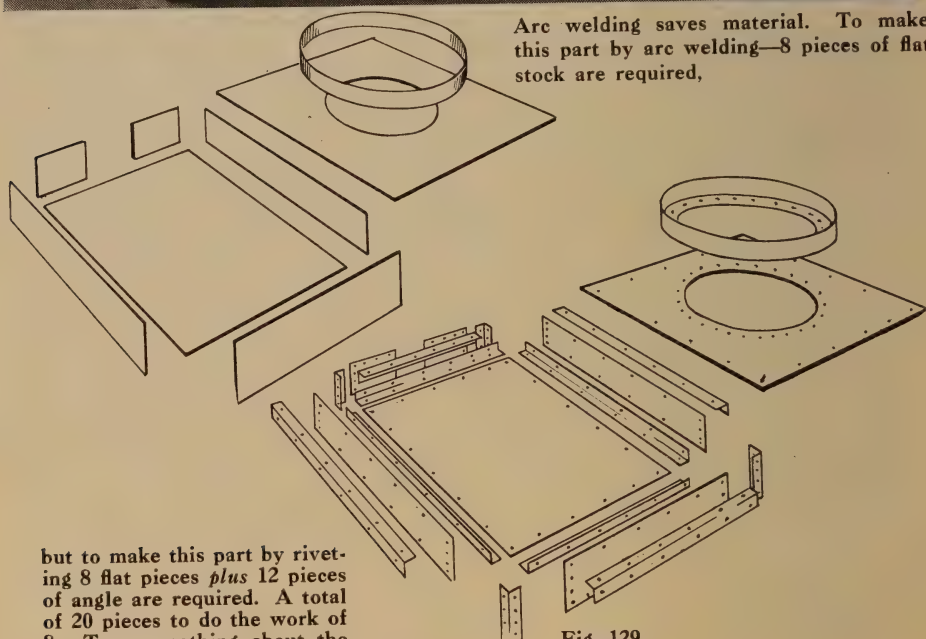


Fig. 128

The oil pan on this turret lathe, manufactured by The Warner & Swasey Co., Cleveland, Ohio, is made of arc-welded steel.



Arc welding saves material. To make this part by arc welding—8 pieces of flat stock are required,



but to make this part by riveting 8 flat pieces *plus* 12 pieces of angle are required. A total of 20 pieces to do the work of 8. To say nothing about the cost of punching rivet holes and driving rivets.

Fig. 129

Arc-Welded Wheels

Arc welding is used extensively in the manufacture of wheels for various purposes.

One example is the wheel for a shop truck, illustrated in figure 130. Like many similar wheels this wheel was formerly made of cast iron. The manner in which steel was substituted is clearly shown in the illustration. The rim is formed by rolling a standard T-bar into a circle

and welding the junction. The hub is made from a short length of standard pipe and the spokes are flat bar stock. All parts are welded and the result is an all-steel wheel, stronger than the cast iron wheel and weighing but one-half as much. The cost of the cast iron wheel was \$1.85 each and the cost of the welded steel wheel \$.68—a saving of more than sixty percent.

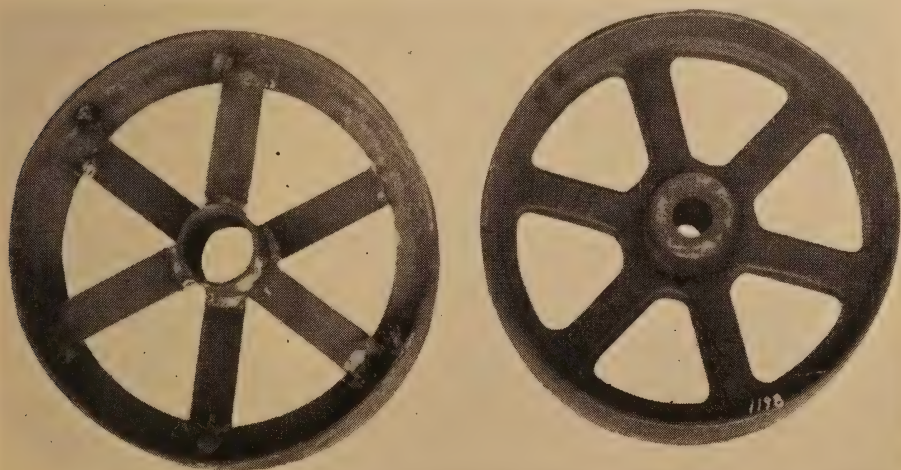


Fig. 130

WHEEL FOR SHOP TRUCK

ARC-WELDED STEEL, WT. 12.5 LBS.

Cost of rolled steel.....	\$.35
Labor cost.....	.33
Total cost.....	\$.68

CAST IRON, WT. 25 LBS.

Cost of rough casting.....	\$1.75
Labor cost	.10
Total cost	\$1.85

The arc-welded wheel is not only cheaper to make but weighs one-half as much as the cast iron wheel.



Fig. 131

There is not a single bolt or rivet in this 1½-ton coal bucket built by the Godfrey Conveyor Company, Elkhart, Indiana. It is arc-welded throughout for strength.

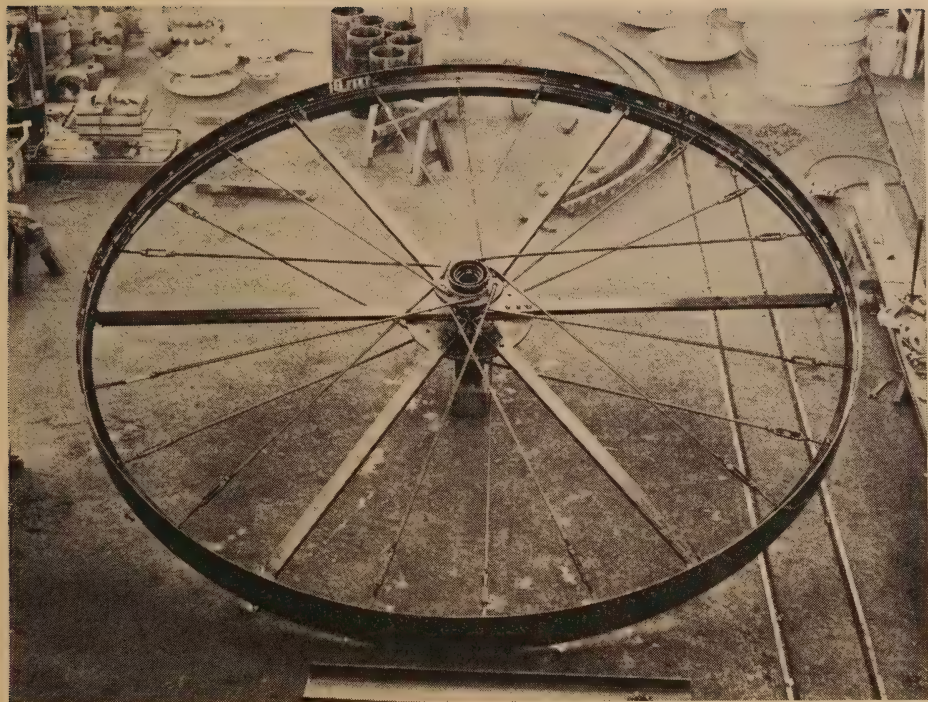


Fig. 132

Eighteen foot band wheel built by the Oil Well Supply Co., Oil City, Pa. By arc-welding the T-iron stiffener to the rim, 176 rivets were eliminated. In addition to reducing the cost, arc-welding made a better product. The smooth outside face of the wheel means longer life to the driving belt.

Large hand wheels such as are used extensively on road building machinery are now made by arc welding from standard pipe of various sizes. The rim of the wheel in figure 133 is made by rolling up a circle of $1\frac{1}{4}$ " pipe. The spokes are of pipe of a smaller diameter welded to the hub. One large manufacturer reports that he keeps two arc welders constantly busy making hand wheels of this nature.

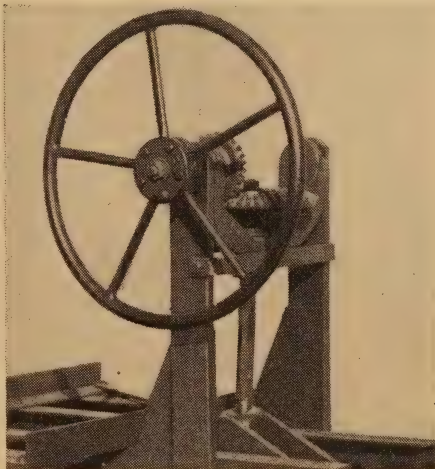


Fig. 133

Hand wheel made of $1\frac{1}{4}$ " pipe with $\frac{3}{4}$ " spokes. Arc welded at all joints. Photograph by courtesy of Killefer Mfg. Co., Los Angeles, Calif.

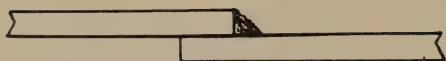


Fig. 134

Single Lap Weld. Suitable for thin sections or where great strength is not required.



Fig. 136

Butt Weld. This is a 100% joint. The edges of the plates should be beveled as shown.

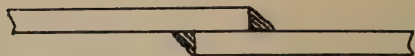


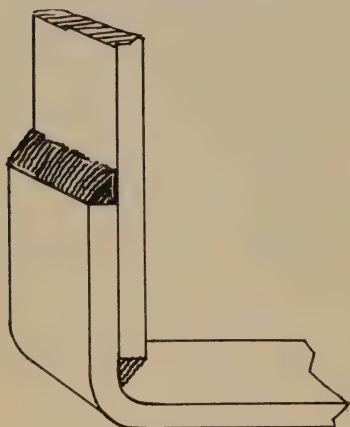
Fig. 135

Double Lap Weld. This joint can be made as strong as the members joined. Note saving in material over double lap riveted joint.

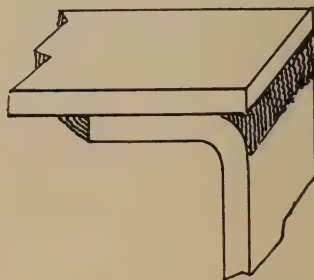


Fig. 137

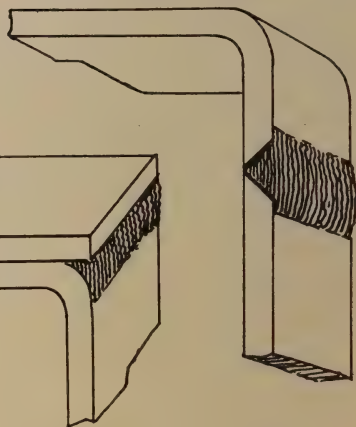
Double riveted joints.



A



B



C

Fig. 138

Three methods of welding flanged heads in cylindrical tanks. Method C is the best practice where maximum strength is required.

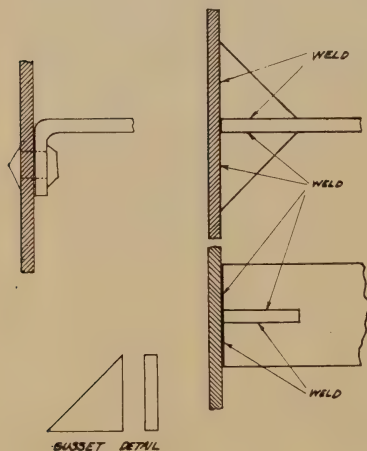


Fig. 139

Method of welding brace in place of riveting.

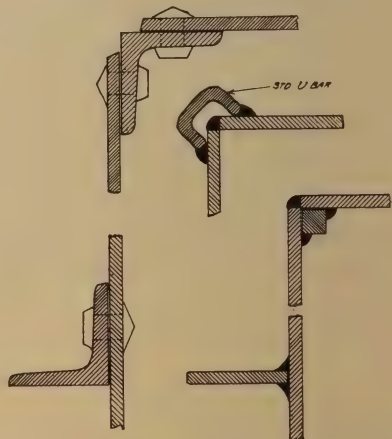


Fig. 140

Welded corner stiffeners.

Typical Welds and Short Cuts

Too much emphasis cannot be placed on the economy of using standard parts in arc-welded construction. In addition to rolled steel shapes,—standard pipe and pipe fittings, standard hinges, standard bolts and nuts and similar parts can often be used to take the place of special castings or forgings.

The drawings on pages 92 and 94 show typical details of arc welded construction making use of standard parts. These drawings merit study. To appreciate the economy of these construction details, it is necessary to visualize the procedure required to get the same results by some other method.

Suppose, for instance, a single T-bolt were required. This T-bolt

could be hand forged, or it could be cast of malleable iron or steel. Any one of these methods would require much more time and would be far more expensive than arc welding. A round steel bar welded to a standard bolt solves the problem.

As another example, suppose that it were desired to fasten a piece of pipe to a channel beam. If a strong, rigid joint were required, it would be necessary to make a special clamp, either cast or forged, to hold the pipe. This clamp would have to be bolted or riveted to the channel beam which would mean drilling four holes in the clamp and in the beam. Then would come the actual assembly.

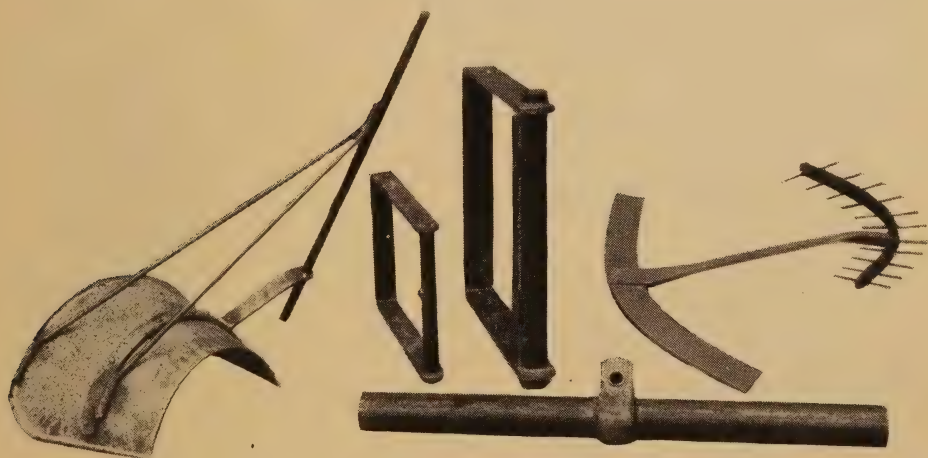


Fig. 141

Machine parts manufactured by The Jaeger Machine Co., Columbus, O. Can any designer think of a more economical method of making these parts?

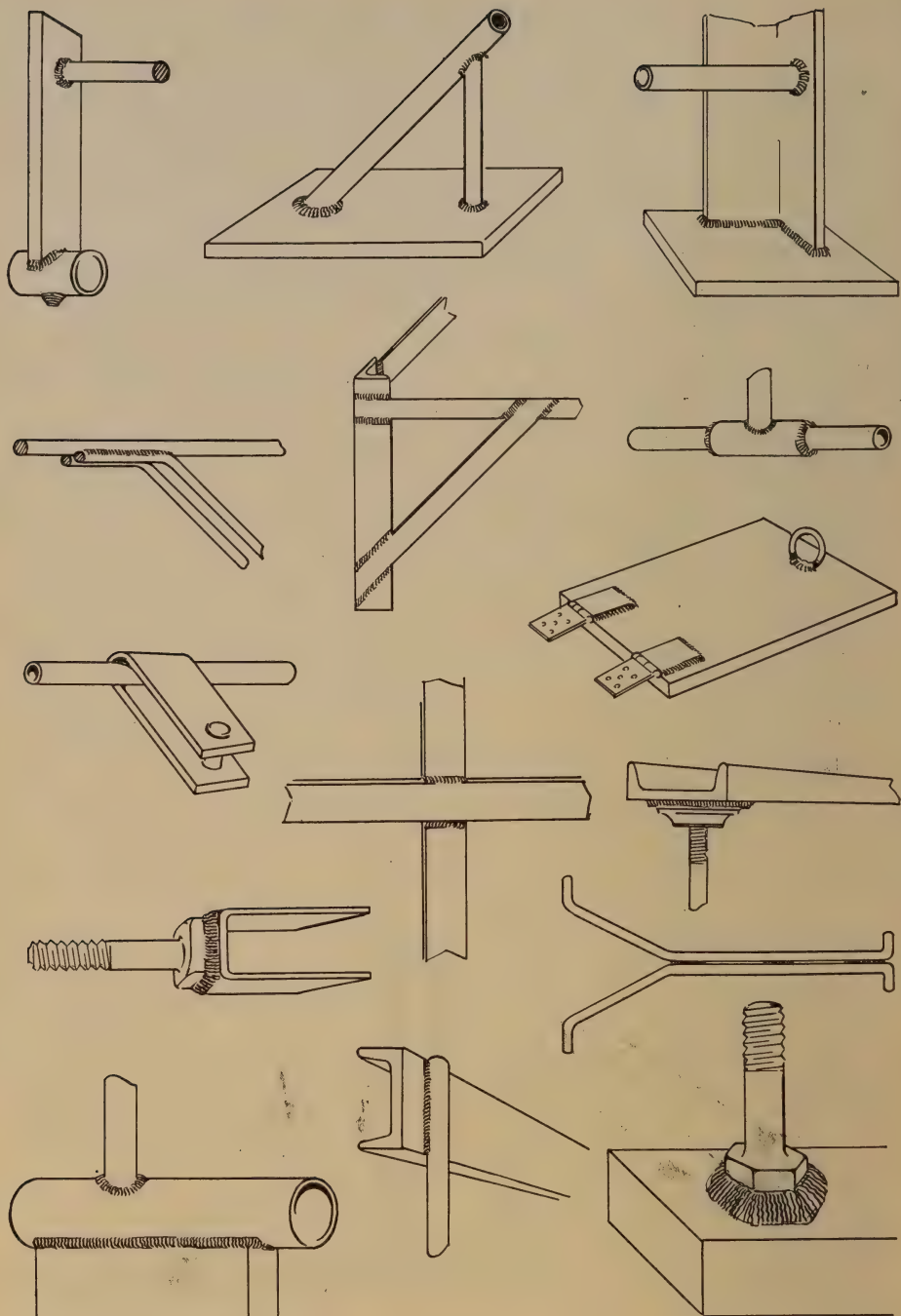


Fig. 142
Typical welds and short cuts.

By arc welding the procedure is much simpler. The pipe is placed in position and molten steel deposited along the edges, making pipe and beam an integral part. The entire job would be finished in less time than it would take a draftsman to make a drawing of the clamp.

Some of the sketches reproduced here are actual details of equipment in regular production, others are suggestions only. The only limit to the use of standard parts is the ingenuity of the designer.

Another important feature of arc welding is the possibility of building up pads, lugs and bosses. Where such a raised projection is necessary it can be made either by welding on a small piece of steel of the proper shape or by depositing metal from the electrode and actually building up a solid homogeneous pad.

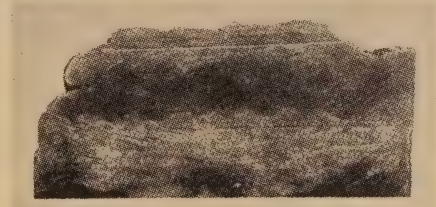
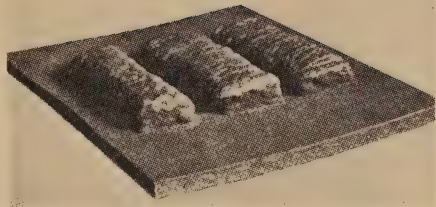


Fig. 143

Pads and bosses can be built up by depositing metal. The illustration shows a cross section of such a pad. Frequent examples of this practice are illustrated in this manual.



Fig. 144

Standard products can be used for special purposes when the designer possesses ingenuity and an arc welder. Here are four money saving examples used on products manufactured by The Jaeger Machine Co., Columbus, O.

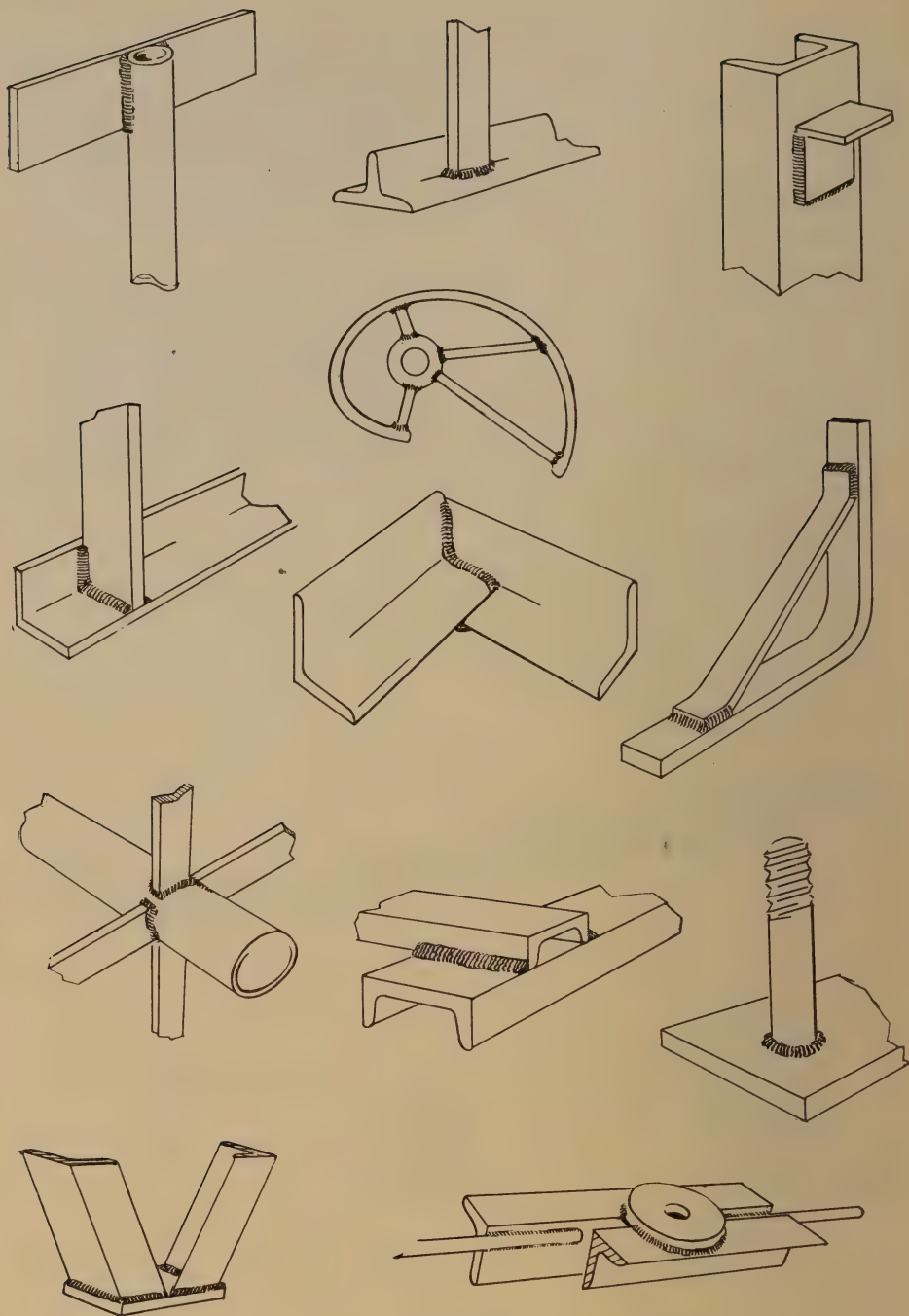


Fig. 145
Typical welds and short cuts.

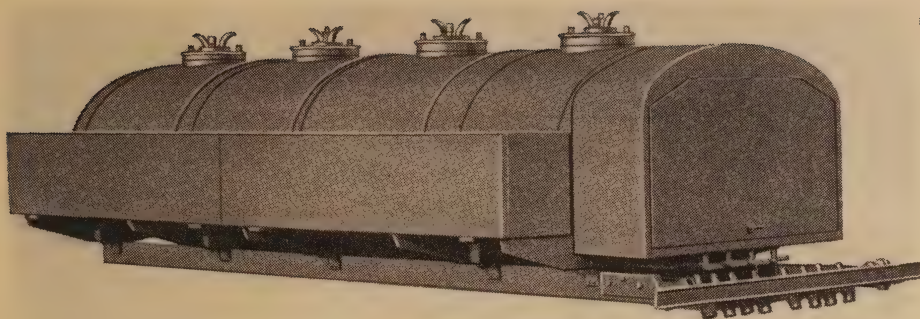


Fig. 146

Arc welding is now used by most manufacturers of tank trucks because an arc welded seam remains permanently tight. The Heil Co., Milwaukee, Wis., manufacturers of all kinds of tanks, were pioneers in the adoption of arc-welding.



Fig. 147

Truck bodies of every description are arc welded by the Truck Equipment Co., Buffalo, N. Y. Welding makes every plate and every brace a single integral piece.



Fig. 148

The Giant Slide at Riverview Park, Detroit, Mich., affords pleasure to thousands of persons each season. Their safety depends on arc-welded construction.

Arc Welded Design for Structures

The use of arc welding for joining the structural steel framework for buildings and bridges is an accomplished fact. A few of the structures made by arc welding were mentioned in an earlier section of this manual. The reason for using arc welding instead of riveting was solely because welding was better and more economical. It is entirely possible to arc-weld the framework for the tallest skyscraper, and eventually arc welding will largely replace riveting in this field.

One of the largest manufacturers of fabricated steel has carried out extensive experiments on arc welding. Their experiments have convinced them of the entire reliability of arc welding and also of the sav-

ings possible by this method. The photographs reproduced here showing typical welded connections were taken from actual members used in construction work by this company.

The details of arc welded designs are very little different from the details of riveted designs.

Figure 149 shows the main girder of a crane runway. This girder consists of a web plate, two angles on the bottom flange, and two angles and a cover plate on the top flange. The illustration clearly shows the method of welding a continuous bead for a distance of 30 inches from each end of the girder, and tack welding the intermediate distance.

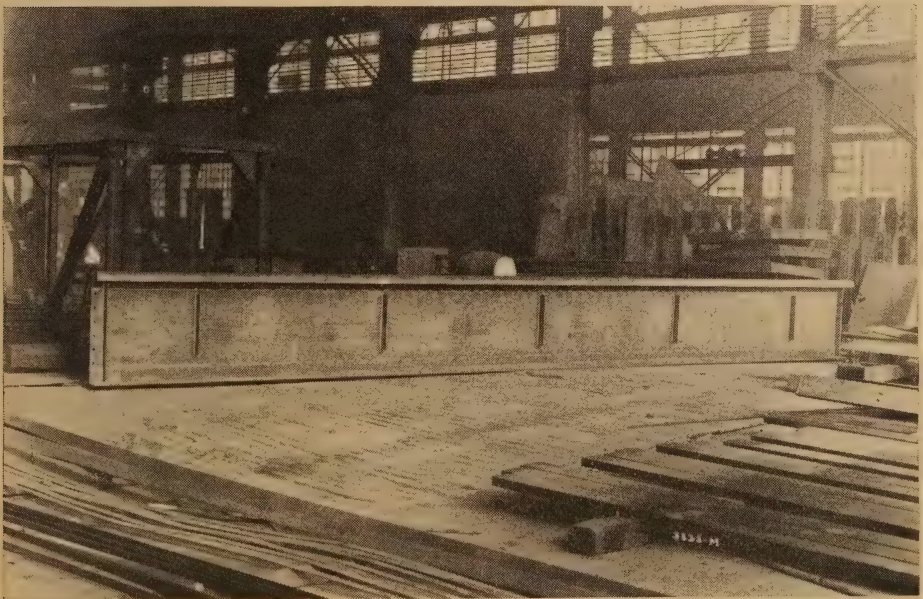


Fig. 149

Main girder of runway for 100-foot span overhead traveling crane.

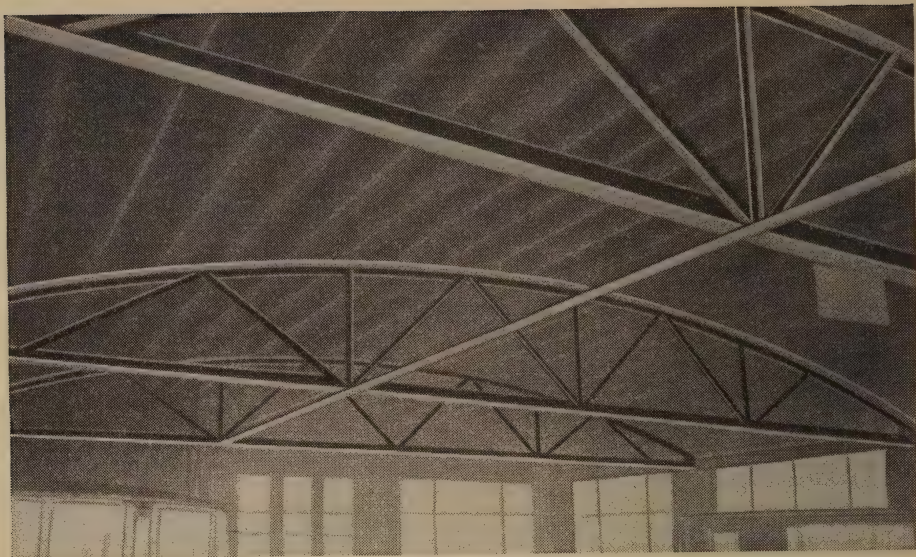


Fig. 150

Roof trusses of arc-welded steel are made for any span from 40 to 60 feet by the Massillon Steel Joist Co., Canton, O.

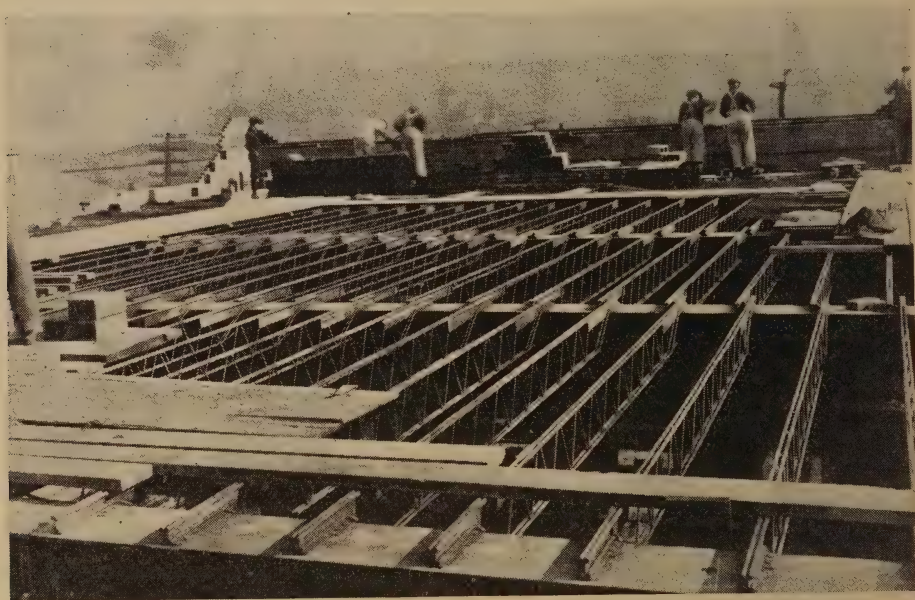


Fig. 151

Arc-welding made the Massillon Bar Joist possible. The design of this joist permits running pipes and conduits in any direction. There is the further advantage of light weight. Manufactured by The Massillon Steel Joist Co., Canton, Ohio.

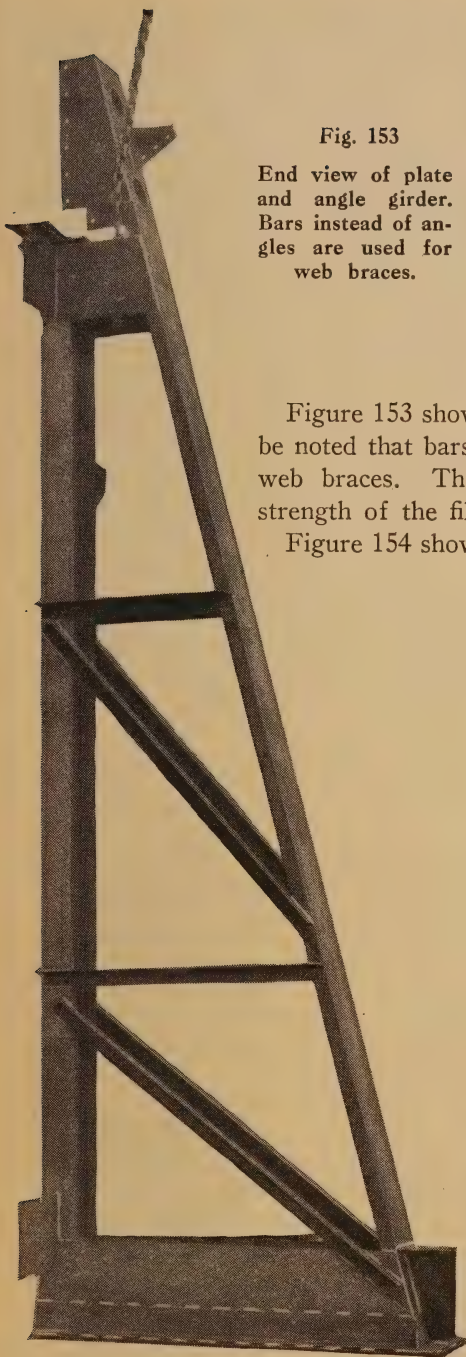


Fig. 152

Column for supporting crane runway
for 100-foot span crane.

Fig. 153

End view of plate
and angle girder.
Bars instead of an-
gles are used for
web braces.

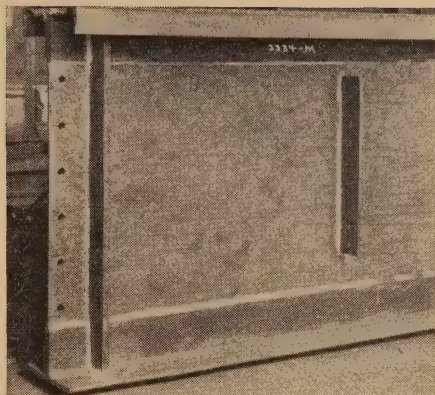


Figure 153 shows an end view of this girder. It will be noted that bars instead of angles were used for the web braces. This is possible because of the great strength of the fillet welds.

Figure 154 shows a plate welded by a fillet onto an I-beam. The strength of this construction was questioned by one of the men in the erection shop and it was decided to make a real test. One man with a twelve pound sledge struck the plate 16 times on one side and 30 times on the other side without doing more than bending the plate. A battering ram, weighing 587 pounds, was then suspended from the crane hook and after 46 blows were struck the weld showed no failure.

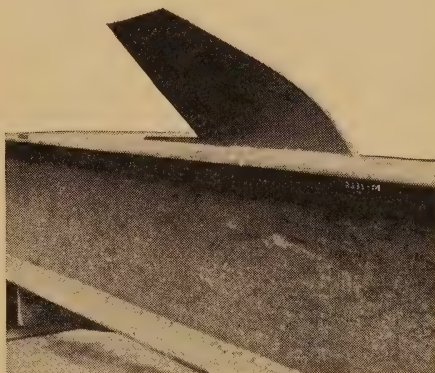


Fig. 154

Forty-six blows with a 12 pound sledge
made no impression on this weld.



Fig. 155

The Diamond Hardware Mfg. Co., Pittsburgh, Pa., arc weld steel roof trusses for small garages, warehouses and factories. These were formerly riveted, but arc welding was found faster and less expensive.

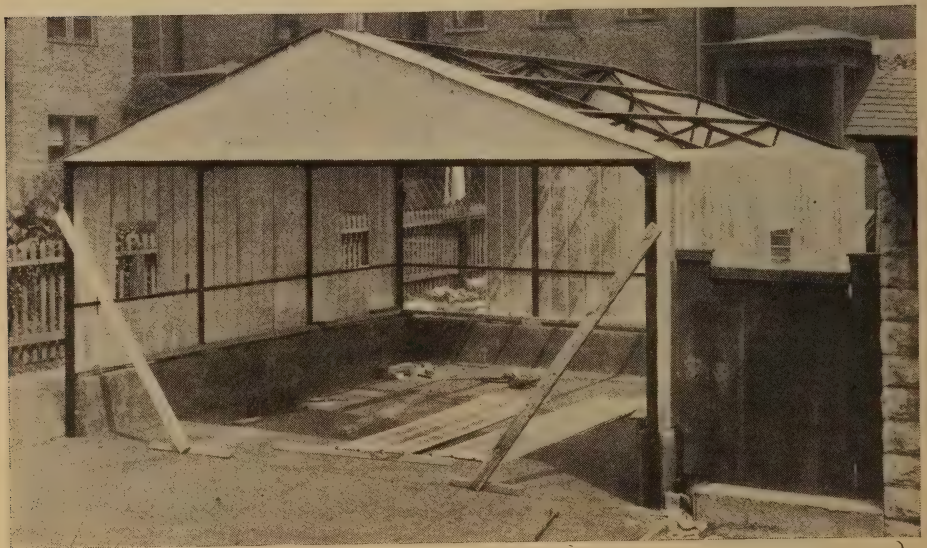


Fig. 156

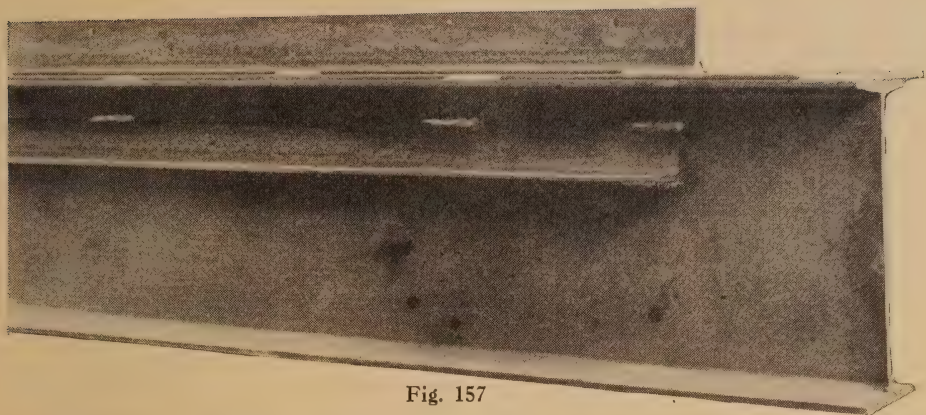


Fig. 157

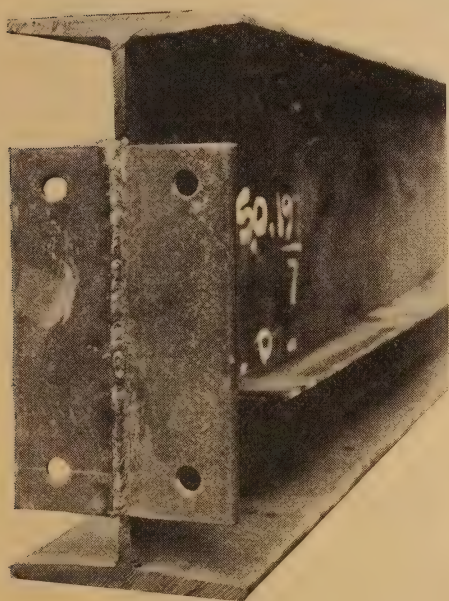


Fig. 158

Figure 157 shows the method employed for welding a lintel used in a brick and steel building in Canton, Ohio. This carries a cover plate for the brick wall and also a shelf angle to support the floor joists. The tack welds are about four inches long.

Figure 158 shows the method of welding end-connection angles, and seat angle construction is shown in figure 159.

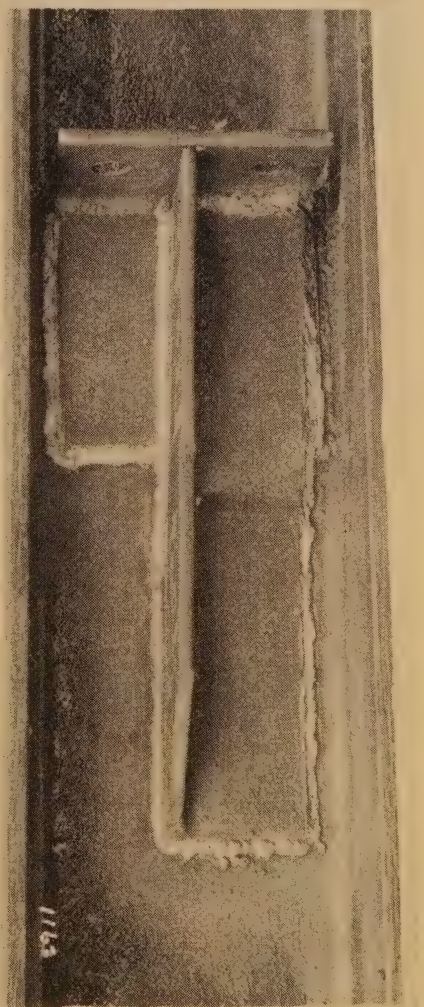


Fig. 159

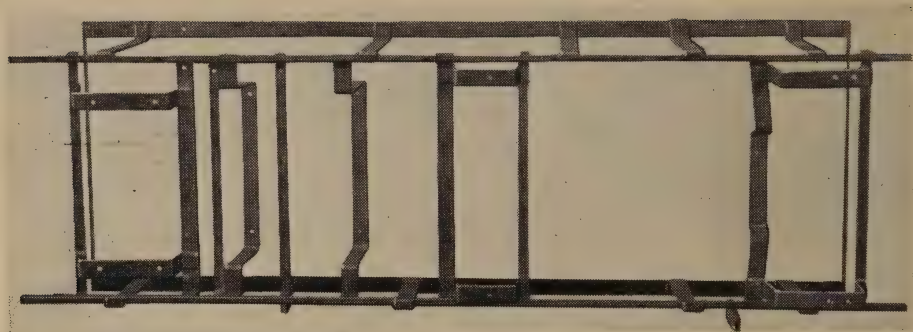


Fig. 160

Template for drilling machine base. The template as well as the product is arc welded.



Fig. 161

Jigs and fixtures arc welded by The Jaeger Machine Company, Columbus, Ohio.

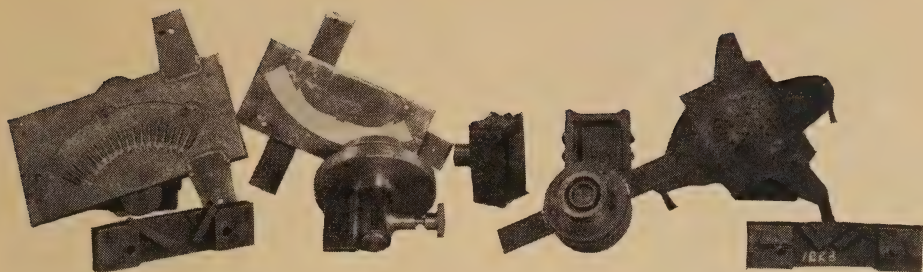


Fig. 162

Punches and strippers made by arc welding. This illustration deserves close study.

Arc Welding in the Tool Room

Manufacturers have long been accustomed to high costs on special tools such as punches and dies and on jigs and fixtures. It is to be expected that where only one or two similar tools are made, that the cost will be considerable. However, arc welding will reduce these costs.

The toolmaker who knows arc welding is in a position to produce special tools more quickly and more economically. Figure 162 shows several punches and strippers made by arc welding. Steel plate replaces castings, eliminating pattern expense. The cost of machine work is reduced by welding on projections and lugs instead of machin-

ing these parts from solid steel.

Arc welding changes the entire conception of machine shop practice because now it is possible to add metal as well as remove it. The metal added is as homogeneous as rolled steel itself. At last the much sought for "adding on tool" is here.

Figures 161 and 163 show machining jigs made by arc welding. Patterns are entirely eliminated. Think of the saving in time to produce these jigs! Standard steel sections are used. The toolmaker puts them together. He does not wait for the patternmaker or the foundryman, but builds direct from his own sketches.

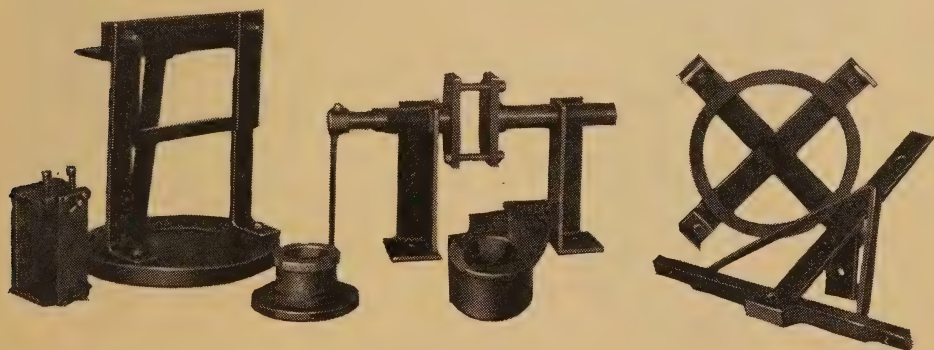


Fig. 163

Jigs and fixtures made by arc welding.

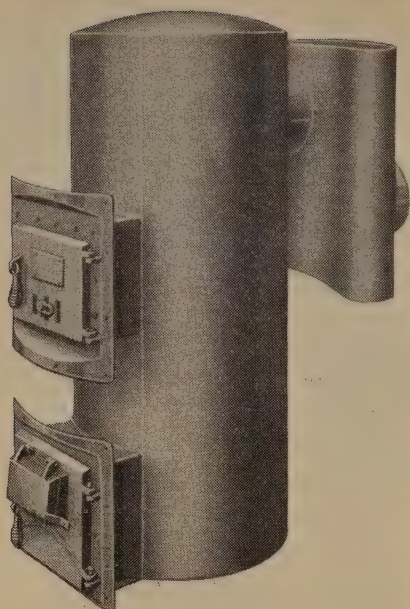


Fig. 164. Dirt and gas cannot escape through walls of arc-welded steel. This seamless furnace is made by The Waterman-Waterbury Co., Minneapolis, Minn.

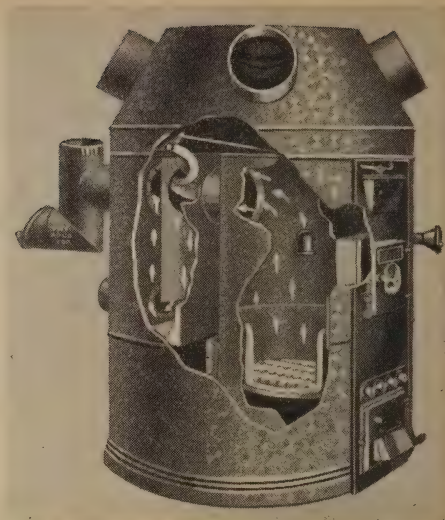


Fig. 165

Steel replaces cast iron in the Robinson Furnace made by The A. H. Robinson Co., Cleveland, Ohio. All seams are arc welded.

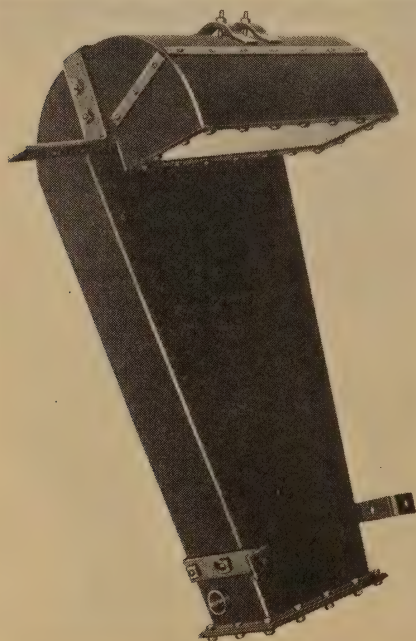


Fig. 166

The Foamite mixing chamber for discharging Firefoam is built of arc-welded steel. This equipment is manufactured by Foamite-Childs Corp., Utica, N. Y.

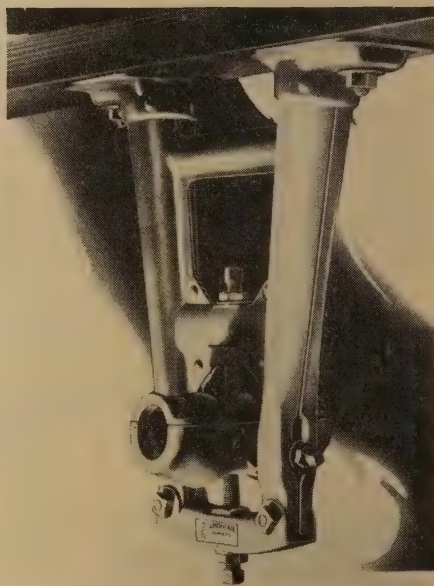


Fig. 167

Arc welding is used to give added stiffness to the American All Pressed Steel Shafting Hanger, made by American Pulley Co., Philadelphia. Steel hangers weigh about half as much as cast iron hangers.

There Is Real Selling Value in Being Different

In redesigning don't try to copy the appearance of the old design—the new design, if successfully engineered, will be sufficiently better and less expensive to overcome any sentimental attachment which tradition-bound customers may have for bulky, massive, cast iron structures.

There is a real selling value in being different, particularly when your product costs less to produce than your competitor's. Freight is often a bar to good markets, and every pound that you can cut off of

the weight of your product represents money saved in transportation costs, whether you sell your product f. o. b. factory, or at your customer's door. Weight saved means money saved all along the line and on a cents-per-pound basis you will more than have the edge on cast iron competitors.

Aim to design something which will do the work in the best possible way and take advantage at the same time of the strength, low cost and lightness of steel.

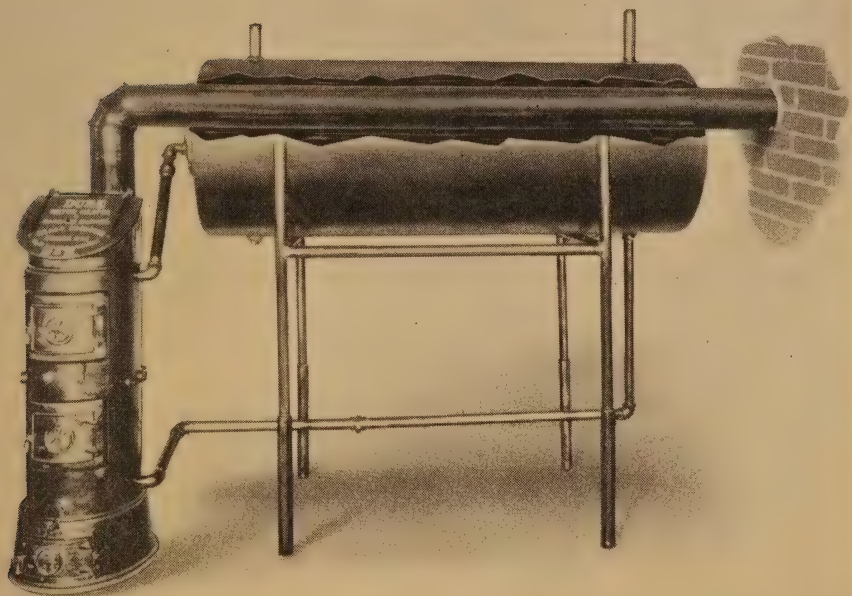


Fig. 168

Dube Water Heater and Garbage Burner built by Grand Crossing Boiler Works, Chicago, Ill. Note how the water tank is supported on a base made of standard pipe arc welded at the joints. The tank is also arc welded.

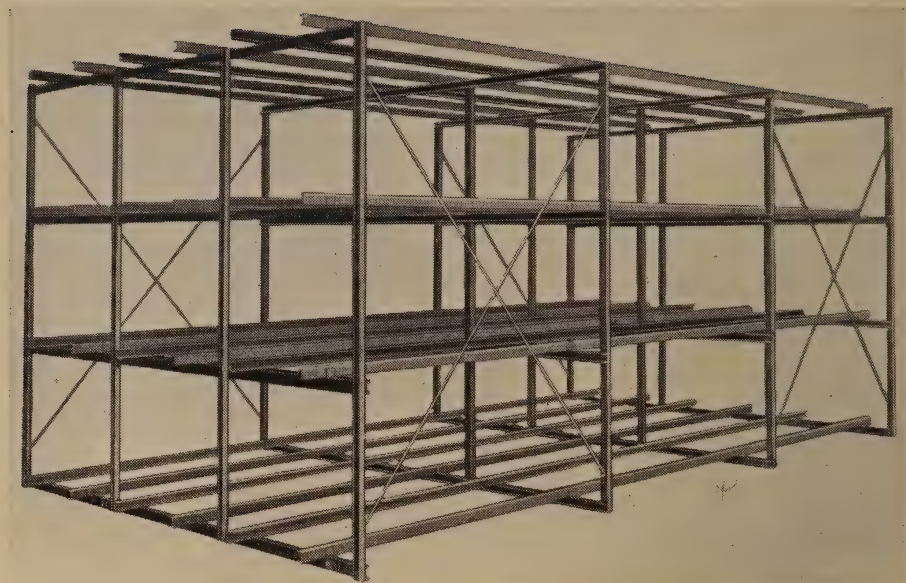


Fig. 169

Arc-welded barrel and drum racks built by Lewis Shepard Co., Boston, Mass. These racks are built of channel sections and combine great strength with light weight.

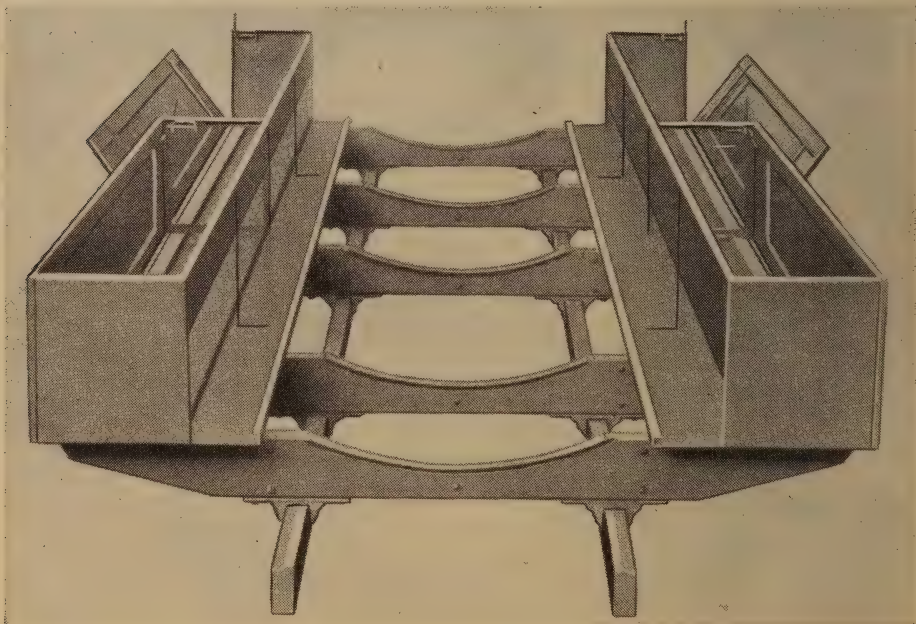


Fig. 170

Cradle for supporting tank on motor truck. Built by The Heil Co., Milwaukee, Wis.

The Arc Welder in Maintenance Work

The master mechanic or millwright will find many uses for arc welding. In erecting countershafting or in mounting motors for individual drive machines, supports of structural steel can be erected quickly and at low cost.

Figure 171 shows a superstructure for carrying the shafting for a cylindrical grinder. Light standard angles are used and all joints are arc welded. Notice the manner in which the I-beam for carrying the chain fall block is supported.



Fig. 171

Countershafting support for cylindrical grinders. Note the method of supporting I-beam for chain fall block.

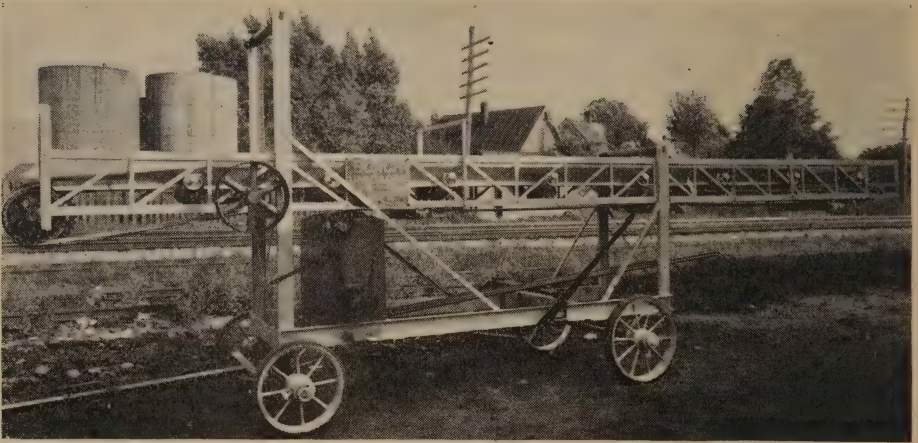


Fig. 172

The truck for this portable unloader, built by The Burch Plow Works Co., Crestline, O., is arc welded for strength and rigidity. There are countless other machines now riveted or bolted where arc welding will add to the strength and at the same time reduce the cost to manufacturers.

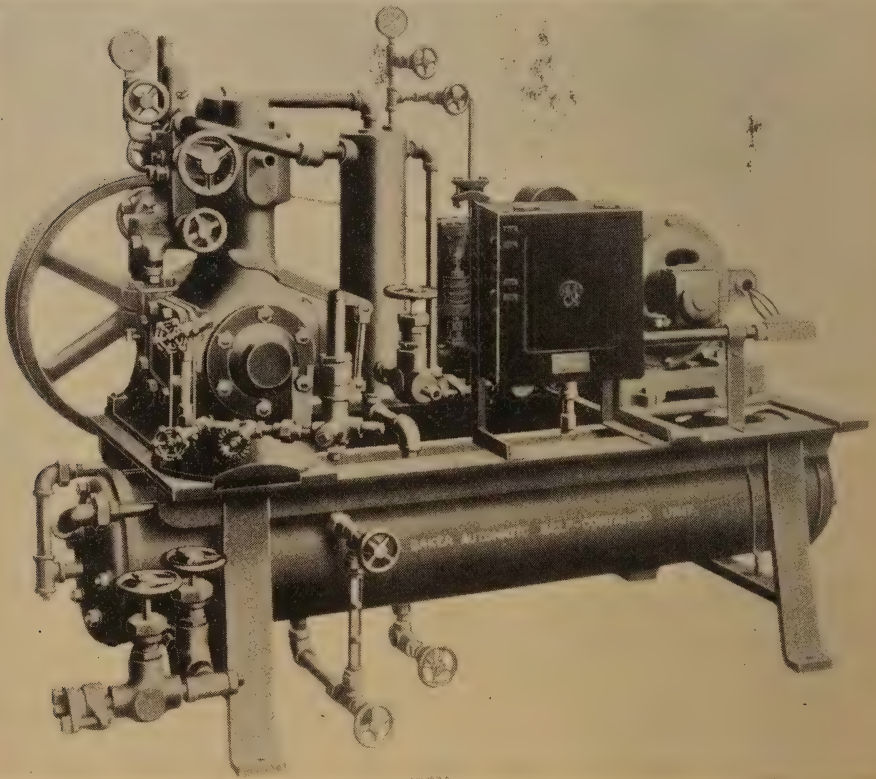


Fig. 173

The base of this self-contained refrigerating unit is made of arc welded steel. Photograph by courtesy of Baker Ice Machine Co., Inc., Omaha, Nebraska.

Twelve Points to Remember in Redesigning

1. The I-beam is the stiffest structural shape for its weight that can be designed. Use it for columns, or for transverse members to resist compression or bending.

2. The angle is strong in both compression or bending, and has the advantage of lending itself readily to arc welding.

3. Welds should be put out of sight to eliminate finishing.

4. Do not go to a special shape unless absolutely necessary, special shapes often mean costly delays. There is usually a way out if the problem is studied thoroughly.

5. Don't feel that it is necessary to make the entire structure of rolled steel. Use castings, forgings or stampings where they are more economical. Arc welding is a new tool, not a fad.

6. A lap weld may save many times the cost of making a butt weld by facilitating assembly and by the elimination of accurate fitting.

7. Chamfering the edges may be, but is not usually, necessary.

8. Use tack weld for assembly and after the structure is assembled, completely weld up the structure. Surprising economies are effected in this way.

9. Use carbon electrode welding when the section is heavy and easy to get at, as it is faster and more economical.

10. Don't expect that you can redesign all of your apparatus at once. Speed is necessary, but speed and ideas do not always go together and ideas are more important.

11. Don't forget that the product you are now making will eventually be made by arc welding. The man who gets the answer first will be the leader and will reap the rewards of the leader.

12. Your engineering department must be "welding minded." Welding is a more useful tool to you than your drawing instruments.

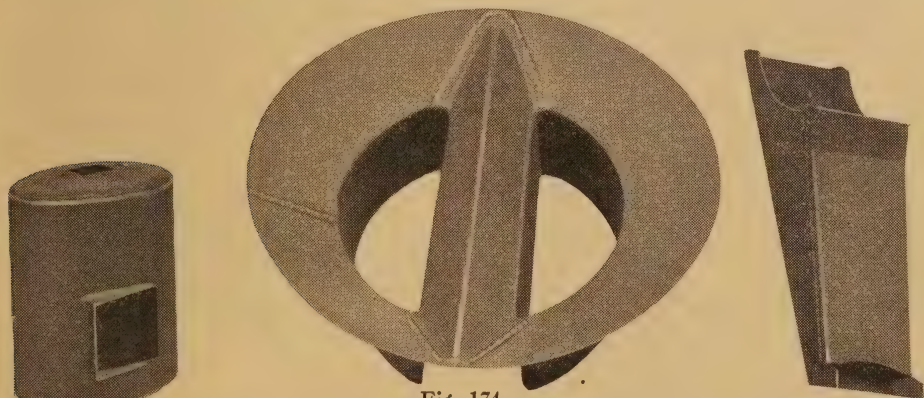


Fig. 174

Arc welding is the most economical method of joining metals whether it is thin sheet or heavy plate. These parts are manufactured by The Jaeger Machine Company, Columbus, Ohio.

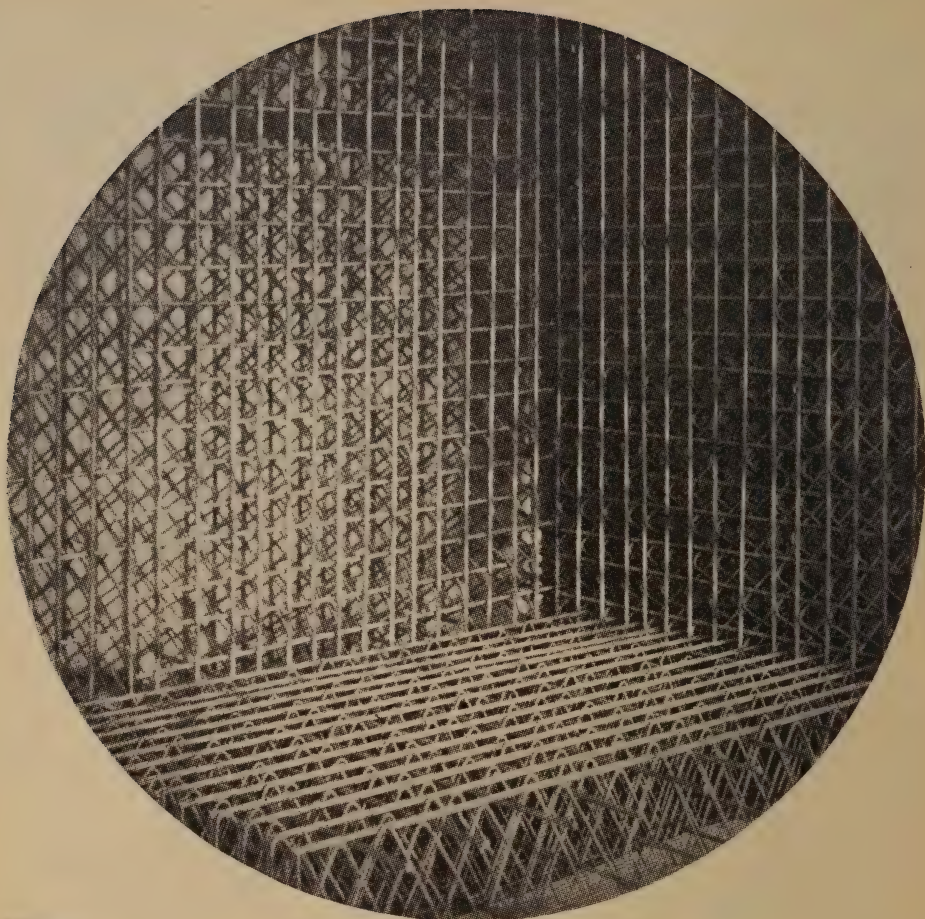


Fig. 175

Arc-welded reinforcing for concrete bank vaults. When this reinforcing is installed every joint is welded, making an integral barrier of steel concrete reinforcement. Vaults of this construction defy fires, earthquakes and organized attacks of mobs. This is one of the applications of arc-welding made by the Massillon Steel Joist Company, Canton, Ohio.

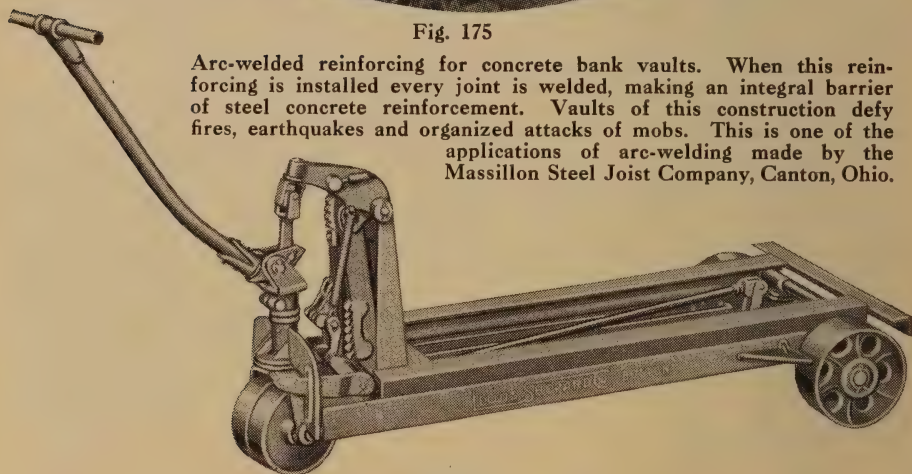


Fig. 176

Lewis-Shepard jacklifts are noted for their sturdy construction. Arc welding helps to maintain their reputation.

CHAPTER V

Strength of Arc Welded Joints

IT has frequently been stated in this manual that arc welding is the strongest method of joining steel parts. To those who have heretofore thought of welding as a sort of patching process, this statement may come as a surprise. It is, however, a literal fact that 100% joints are regularly made by arc welding, and the following discussion will show how this is possible.

Strength of Butt Welds

Let us consider, first, the butt weld. This style of joint is used chiefly where the parts are in tension. Since the metal comprising the weld has the properties of cast steel, its tensile strength is the same as that of cast steel. This is less than the tensile strength of rolled steel. However, by depositing a sufficiently large cross section of metal, the tensile strength of the weld can be built up to an amount equal to, or greater than, the strength of the plates joined. If a bead equal to 15% of the thickness of the plate be deposited on both sides, the strength of the weld will be equal to the strength of the plate.

Strength of Lap Welds

In a lap weld subjected to tension the weld is subjected to a bending stress as well as a tensile stress. The amount of the bending stress depends on the thickness of the plates. In practice it has been found that when a bead of welding metal equal to the thickness of the plates is deposited on both edges, as shown in

the illustration, the strength of the weld will be approximately equal to the strength of the plates joined.



Fig. 177

A single lap joint should not be used to join thick plates. The stress on this joint is not pure tension, but a combination of tension and bending.



Fig. 178

In riveted construction it is customary to use a butt strap as shown.



Fig. 179

In arc-welded construction it is only necessary to weld both sides of the plates. This joint is as strong as the members joined.

In a lap weld the metal comprising the weld is in shear. It may be in either transverse shear or longitudinal shear. Experiments have shown that welds in transverse shear are stronger than welds in longitudinal shear.

In sketch 180, the metal deposited along the edge c is about 30% stronger than the same metal laid along edges d or e.

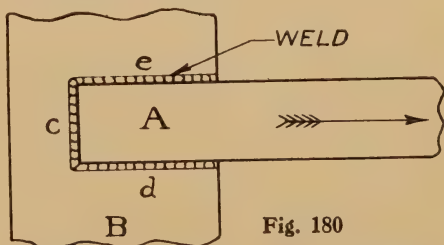


Fig. 180

Metal deposited along edge c is about 30 percent stronger than the same metal deposited along edge d or e.

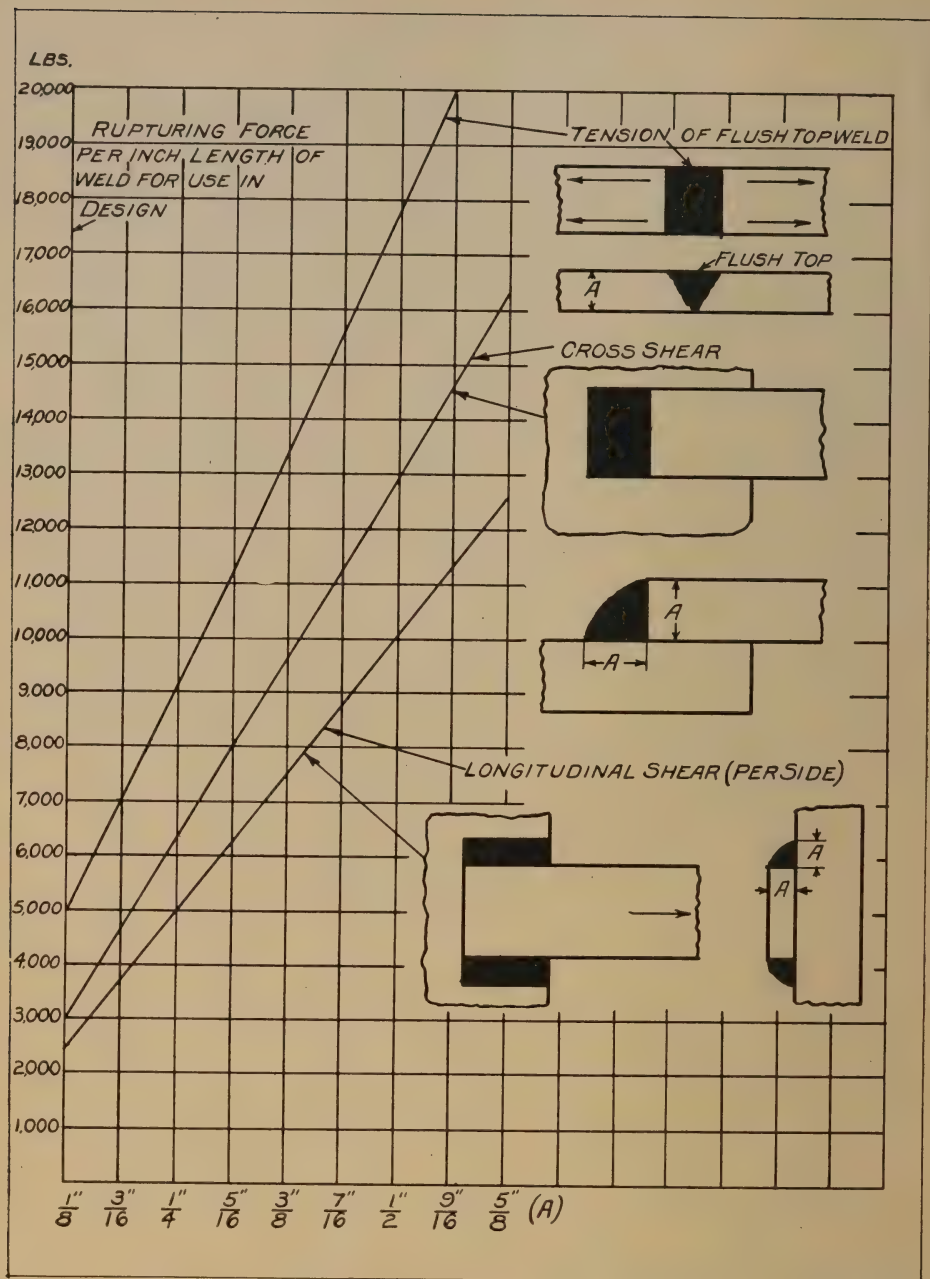


Fig. 181

Rupturing force per linear inch of weld.

Strength of Fillet Welds

The strength of fillet welds depends entirely upon the amount of metal deposited. If sufficient metal is deposited on both sides of the

plate, the strength of the weld can be made far greater than the strength of the plates themselves.

Strength of Rivet Welds

The rivet weld is not used primarily for strength. It is not possible to obtain a 100% joint by this process any more than a 100% joint can be made by ordinary riveting. The rivet weld is stronger

than ordinary riveting, because the welding metal completely fills the hole and is integral with the plates themselves. There is no possibility of weaving in a rivet-welded joint.

Rupturing Force Per Linear Inch of Weld

The chart reproduced on Page 112 shows the rupturing force per linear inch of weld. From this chart the proper length of weld for any style of joint can be computed. The values given are conservative and designs based upon them will be amply safe. Since these are rupturing forces they correspond to ultimate strength given in tables on strength of materials. In applying these figures the customary factor of

safety should be used as in the case of ultimate strength of other materials. In the case of welds less than 6" long it is customary to add $\frac{1}{2}$ " to the theoretical length of weld to allow for the starting and stopping of the arc. The curves for both cross shear and longitudinal shear are based upon bead sections convex outward as shown in Figure 181. Greater convexity will increase the strength and lesser convexity will decrease the strength.

EFFICIENCY OF RIVETED JOINTS

							
PLATE THICKNESS	NORMAL RIVET DIAM. INCHES	DIAM. DRIVEN RIVETS INCHES	RIVETS IN SINGLE SHEAR		RIVETS IN DOUBLE SHEAR		
			PITCH INCHES	EFFICIENCY η	PITCH INCHES	EFFICIENCY η	
SINGLE RIVETED STEEL JOINTS							
$\frac{5}{16}$	$\frac{11}{16}$	0.72	1.79	0.54	2.56	0.65	
$\frac{3}{8}$	$\frac{3}{4}$	0.78	1.82	0.51	2.58	0.63	
$\frac{7}{16}$	$\frac{13}{16}$	0.85	1.91	0.50	2.68	0.61	
$\frac{1}{2}$	$\frac{7}{8}$	0.92	2.01	0.49	2.80	0.60	
$\frac{5}{8}$	$1\frac{1}{16}$	0.98	2.00	0.45	2.70	0.58	
$\frac{3}{4}$	$1\frac{1}{8}$	1.17	2.35	0.45	3.24	0.58	
$\frac{7}{8}$	$1\frac{3}{16}$	1.23	2.46	0.45	3.18	0.56	
1	$1\frac{5}{16}$	1.36	2.72	0.45	3.45	0.55	
DOUBLE RIVETED JOINTS-MILD STEEL							
$\frac{5}{16}$	$\frac{11}{16}$	0.72	2.83	0.67	4.44	0.76	
$\frac{3}{8}$	$\frac{3}{4}$	0.78	2.85	0.66	4.44	0.74	
$\frac{7}{16}$	$\frac{13}{16}$	0.85	2.96	0.64	4.57	0.73	
$\frac{1}{2}$	$\frac{7}{8}$	0.92	3.08	0.63	4.73	0.73	
$\frac{5}{8}$	$1\frac{1}{16}$	0.98	2.95	0.60	4.46	0.70	
$\frac{3}{4}$	$1\frac{1}{8}$	1.10	3.16	0.59	4.73	0.69	
$\frac{7}{8}$	$1\frac{1}{4}$	1.17	3.17	0.57	4.71	0.68	
1	$1\frac{1}{2}$	1.30	3.46	0.56	5.11	0.68	
$1\frac{1}{8}$	$1\frac{9}{32}$	1.33	3.33	0.54	4.87	0.66	
$1\frac{1}{4}$	$1\frac{11}{32}$	1.40	3.40	0.53	4.94	0.65	
LET p = PITCH OF RIVETS, d = DIAMETER OF DRIVEN RIVETS; η = EFFICIENCY OR RATIO OF STRENGTH OF JOINT TO STRENGTH OF SOLID PLATE; THEN: $\eta = \frac{p-d}{p} \times .90$							

Fig. 182

Comparative Strength of Welded and Riveted Joints

In an analysis of the strength of welded joints it is convenient to compare the welded joint with the corresponding style of riveted joint. The simplest form of welded joint is the lap weld. This welded joint corresponds to a lap riveted joint. It may be single lap welded or double lap welded just as a joint may be single riveted or double riveted.

In a lap-riveted joint there are three ways in which failure may occur:

1. The plate may crack along the line of rivet holes.
2. The rivets may shear off.
3. The plates may tear out at the ends.

In a riveted joint designed for maximum strength in tension the rivet spacing, size of rivets, and distance from end of plate must be carefully determined. In practice tables are used, based on theoretical computations plus the results of practical experience. Such a table is given on page 114. It will be seen from this table that the efficiency of a properly made riveted joint ranges from 45 to 76 percent.

In welding, the plates to be joined are not weakened by punched holes. Therefore, it is apparent that two of the three causes of failure in riveted joints are avoided by welded construction. The plates at the joints are full strength, and are no more liable to fail at the joint than at any other point along their lengths.

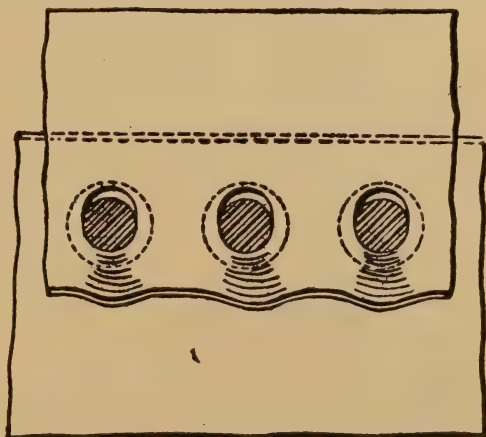
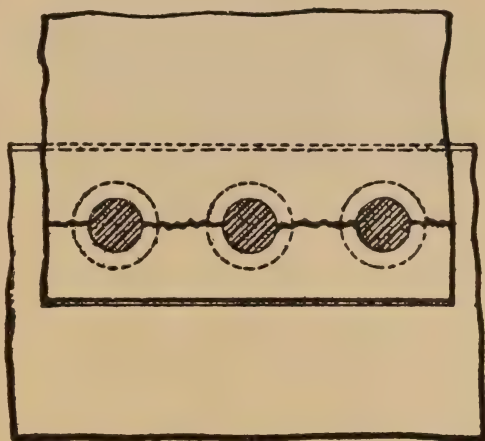


Fig. 183

Riveted joints fail in three ways. Plates crack along line of rivet holes. Rivets shear off. Plates tear out at end.

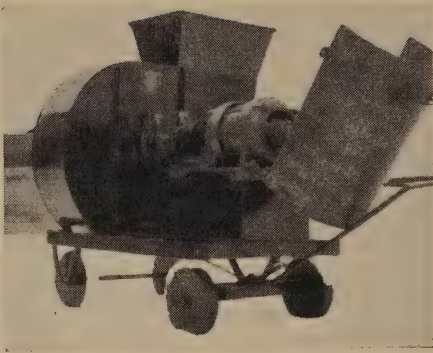


Fig. 184

Kiln Accelerator Fan, manufactured by Robinson Ventilating Co., Pittsburgh, Pa. The fan blades, formerly of cast iron, are now arc-welded steel. Welding has superseded riveting throughout.

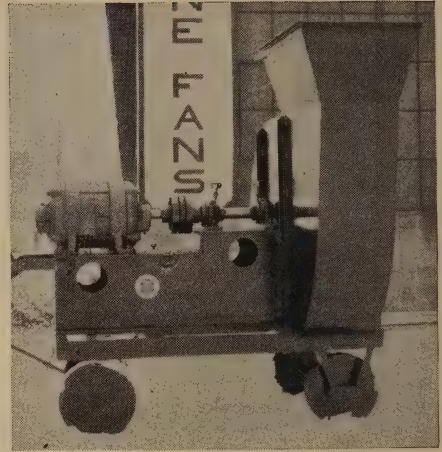


Fig. 185

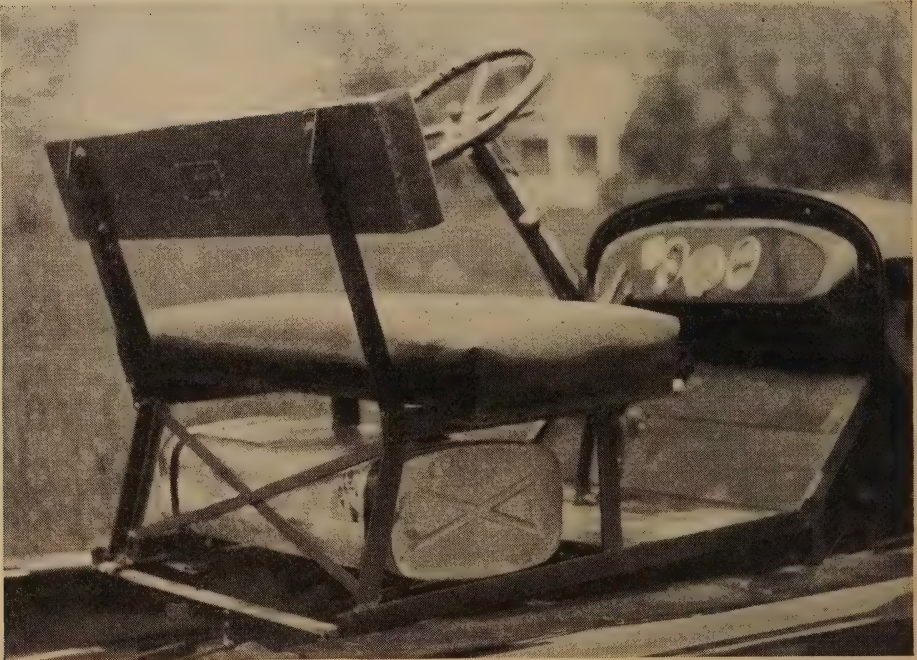


Fig. 186

Seat assembly for Ford chassis completely arc welded by W. C. Nabors, Mansfield, La.

A handy table is reproduced below, showing the size of weld, equivalent in strength to rivets of various sizes.

In computing the size of welds equivalent in shearing strength to rivets of various diameters, the same factor of safety has been used in both cases.

These values for length of weld are derived from the curve of cross shear in Figure 181. A safety factor of 4 was used and a $\frac{1}{2}$ " added to the theoretical length. In case rivets are to be replaced by weld in longitudinal shear the table may be re-computed by the use of the curve for longitudinal shear in Figure 181, or substantially the same results

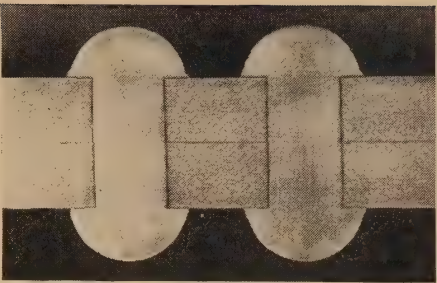


Fig. 187

Cross section of a riveted joint. Note how, in cooling, the rivets have shrunk away from the sides of the rivet holes. This illustrates one great weakness in riveted construction.

may be gotten by simply increasing the length of weld given in the above table by 30%.

SHEARING VALUES FOR WELDS AND EQUIVALENT SIZE OF RIVETS

		$\frac{1}{4}$ " Bead		$\frac{5}{16}$ " Bead		$\frac{3}{8}$ " Bead		$\frac{1}{2}$ " Bead		$\frac{5}{8}$ " Bead	
Size of Rivet, inches	Shearing Value of Rivet at 10000 #/□ lbs.	Shearing Value per inch of Bead, lbs.	Length of Bead, inches	Shearing Value per inch of Bead, lbs.	Length of Bead, inches	Shearing Value per inch of Bead, lbs.	Length of Bead, inches	Shearing Value per inch of Bead, lbs.	Length of Bead, inches	Shearing Value per inch of Bead, lbs.	Length of Bead, inches
$\frac{1}{2}$	1960	1600	$1\frac{3}{4}$	2000	$1\frac{1}{2}$	2400	$1\frac{3}{8}$	3200	$1\frac{1}{8}$	4100	1
$\frac{5}{8}$	3070	1600	$2\frac{1}{2}$	2000	2	2400	$1\frac{3}{4}$	3200	$1\frac{1}{4}$	4100	$1\frac{1}{4}$
$\frac{3}{4}$	4420	1600	$3\frac{1}{4}$	2000	$2\frac{3}{4}$	2400	$2\frac{3}{8}$	3200	$1\frac{7}{8}$	4100	$1\frac{1}{2}$
$\frac{7}{8}$	6010	1600	$4\frac{1}{4}$	2000	$3\frac{1}{2}$	2400	3	3200	$2\frac{3}{8}$	4100	2
1	7850	1600	$5\frac{1}{2}$	2000	$4\frac{1}{2}$	2400	$3\frac{3}{4}$	3200	3	4100	$2\frac{1}{2}$

$\frac{1}{2}$ " added to theoretical length of weld.

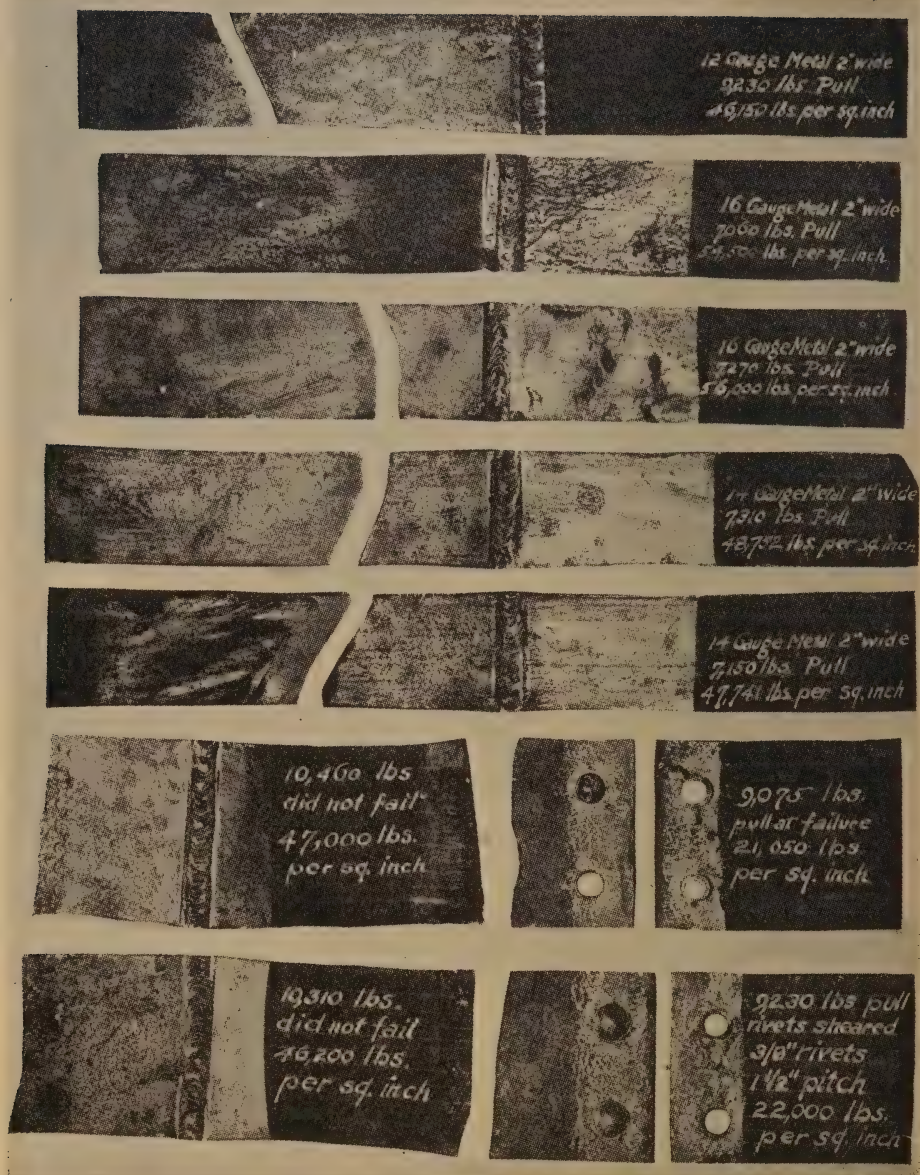


Fig. 188

Tension tests of welded and riveted joints.

Tests of Welded Joints

A striking example of the superiority of welded joints over riveted joints, where subjected to alternating stresses, is illustrated by the two tests described below.

For the first test a section was made up of the same material and by the same methods as used in the manufacture of a well known motor truck frame. This section was subjected to repeated alternating stress by mounting it on a shaper base as shown in the illustration. At 200 alternations of the stress the top rivets in the gusset plates became loose. The second and third pairs of rivets in the gusset plates failed, as shown on the chart below. Next the five rivets in the angle connected to the channel worked loose. Following this the two upper rivets at the far end of the I-beam section became loose, and failure occurred where the channel section had been weakened by the rivet holes.

to the same test as the riveted section and after 24,900 alternations, failure occurred in the channel *outside the weld*.

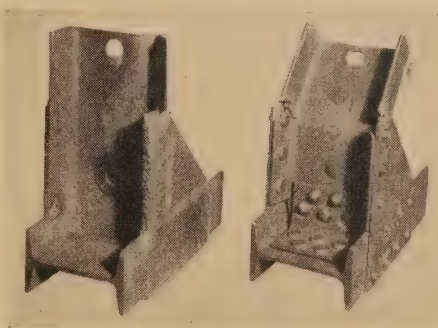


Fig. 189

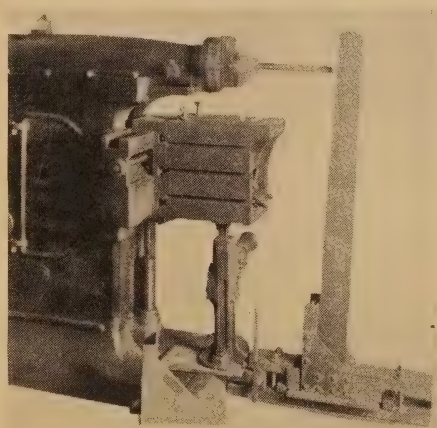


Fig. 190

RESULTS OF TEST. SHOWING PROGRESSIVE FAILURE OF RIVETED PIECE AND HIGH RESISTANCE TO FAILURE OF ELECTRIC ARC WELDED PIECE

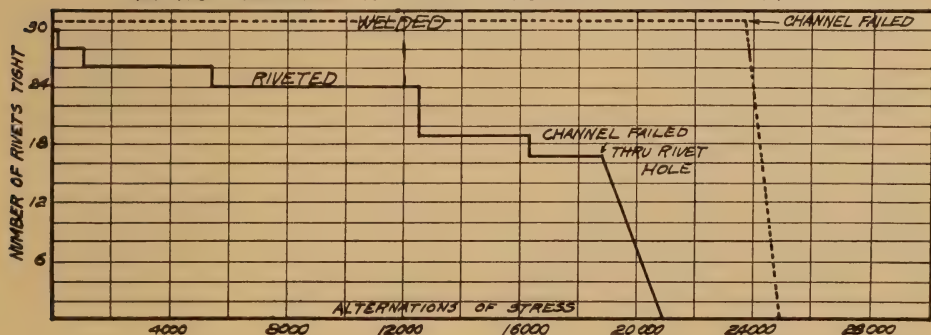


Fig. 191

Alternating stress test riveted joint—welded joint.

Since in riveted construction, the actual strength of a joint is materially lessened the instant that one rivet works loose it is apparent that 200 alternations in the stress were sufficient to cause incipient failure. On the other hand in the welded construction, the joint proved stronger than the members joined. The results of a similar test with a simple T-section are shown graphically in the chart below. Here again the riveted joint failed where the members had been weakened by rivet holes. The welded joint proved far stronger and failure occurred outside the weld.

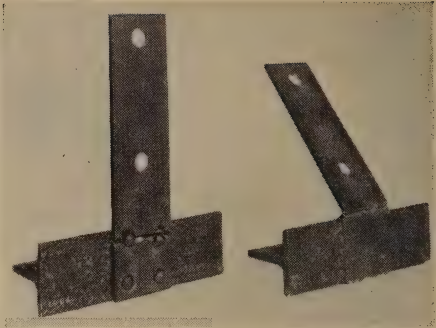


Fig. 192

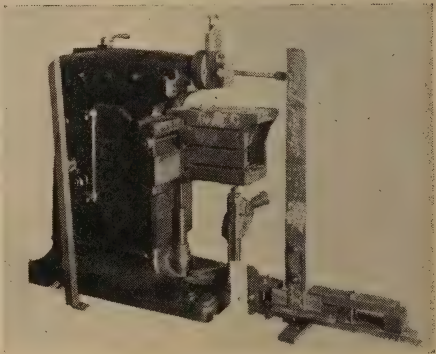


Fig. 193

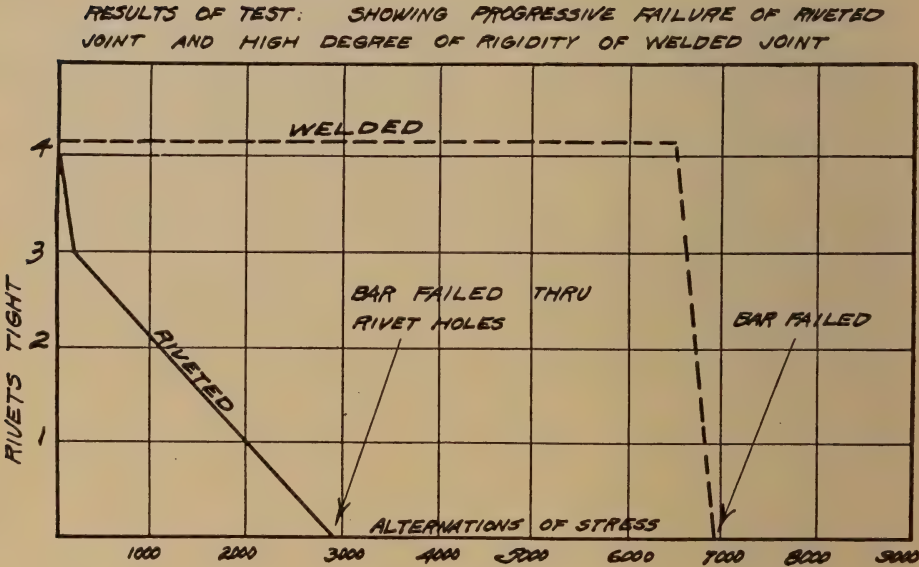


Fig. 194

Alternating stress test riveted joint—welded joint.

Welded Joints Are Reliable

Naturally the human element enters into the construction of a welded joint just as it does into the construction of a riveted joint. A riveted joint, even though correctly designed, may not develop its full strength because of improper workmanship. It very frequently happens, particularly in field riveting, that the holes in two members do not register properly. It is necessary then to ream the holes before the rivet can be driven. This results in an oval shaped hole which the rivet can not possibly fill. The rivet itself is deformed and the joint will be far below its computed strength. In structural work it is frequently necessary to force the rivet holes into alignment by driving drift pins. This means that when the joint is complete there will be an additional stress on it, due to the tension in the member forced into place. There is the additional danger of driving burned rivets or rivets which are too cold. Both of these are well recognized causes for failure in riveted joints.

It is a fact that because of lack of familiarity with the welding process there exists a prejudice on the part of some people against welded construction. If one will stop to realize that every time one rides on a steam train his very life depends on the strength of arc welding, it will be seen that this prejudice is unwarranted. Arc welding is used extensively in the manufacture and maintenance of steam locomotives. The boiler flues are welded into the back flue sheets, broken cylinders and even broken main frames are repaired by arc welding. It would be difficult to conceive a more severe test of dependability, or a test where a failure would be more disastrous.

Welded joints can be inspected with the same degree of certainty as riveted joints. Visual inspection can not be depended upon one hundred percent in either case. If proper workmanship is employed a welded joint can be relied on to develop its theoretical strength.



Fig. 195

Arc welding the main frame on a passenger locomotive. What greater proof could be found of the dependability of arc welding! The railroads were among the first to see the possibilities of arc welding.

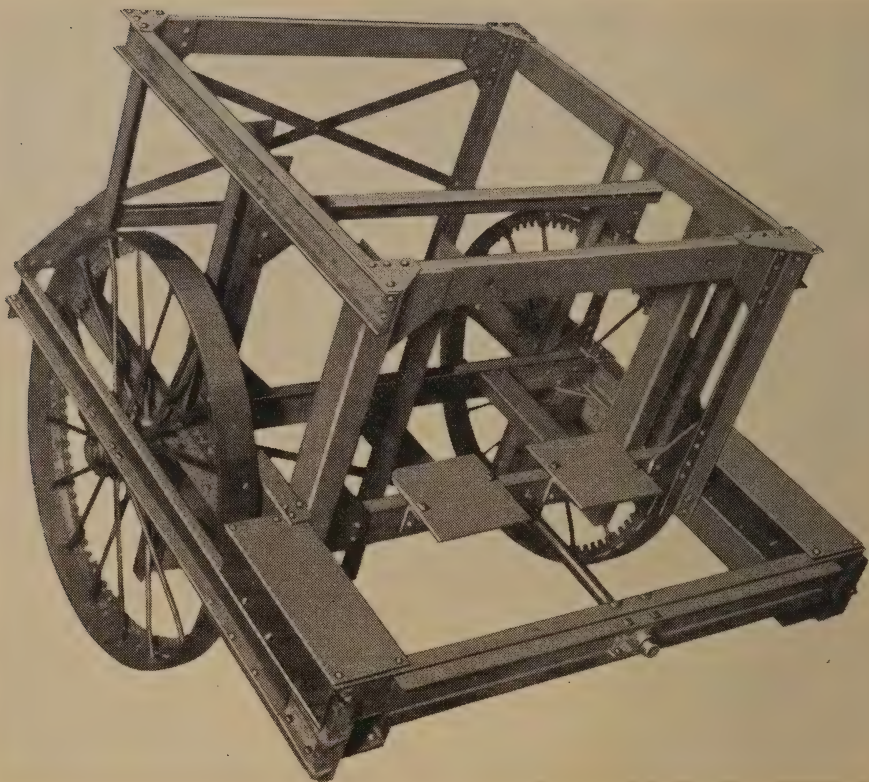


Fig. 196

The frame for this foundry sand cutting machine was formerly made by riveting at a cost of approximately \$200.00. Arc welding reduced this cost to less than \$60.00. Manufactured by the Production Equipment Co., 1521 Windsor Ave., Cleveland, Ohio.

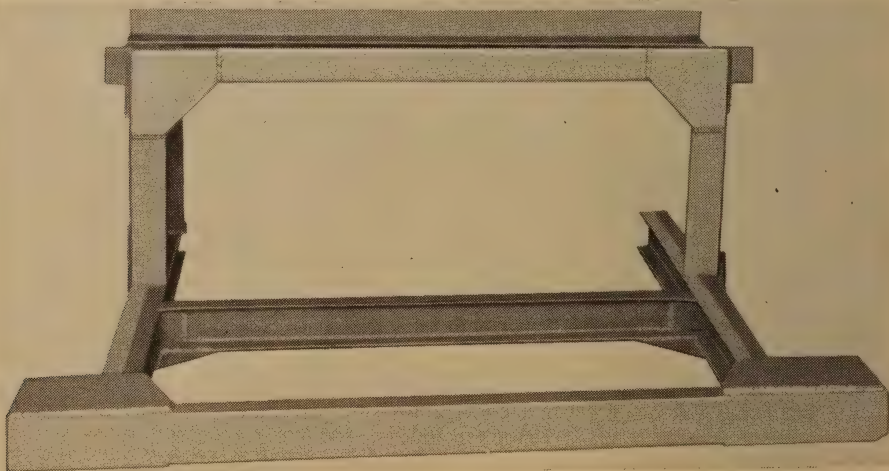


Fig. 197

CHAPTER VI

The Speed and Cost of Welding

ARC welding is cheaper than riveting and cheaper than any other method of welding. This is true because in arc welding, power is utilized more efficiently than in any other method of joining metals.

The power required to operate an arc welder is just about equal to the power required to operate one compressed-air riveting gun. The labor cost is of course much less than for riveting as one welder does the work of an entire riveting crew.

Arc welding utilizes power more

efficiently than gas welding because the electric current is transformed directly into heat and the heat is developed within the metals to be welded. In gas welding, heat is generated by the burning of gas which was originally produced by electricity. This process of transforming electric current into heat is indirect and therefore wasteful. Furthermore, the heat is developed at a point outside the weld and a large part of the heat of the flame is dissipated.

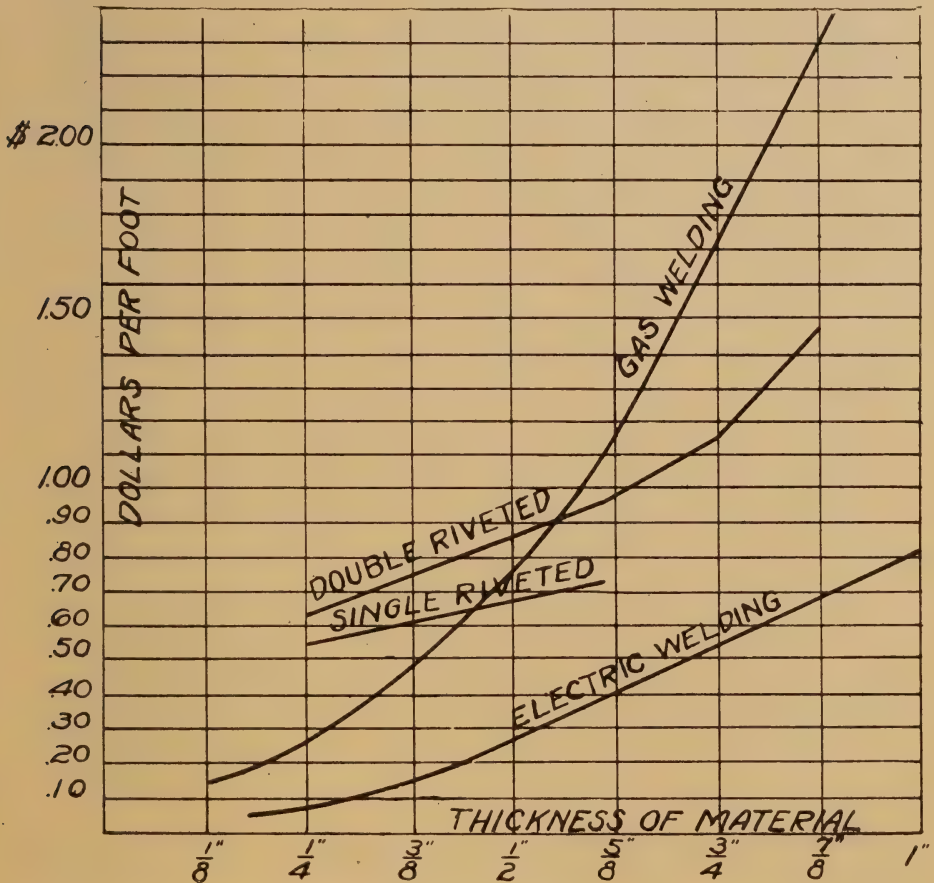


Fig. 198. Comparative costs of riveting, gas welding and arc welding based on continuous operation.

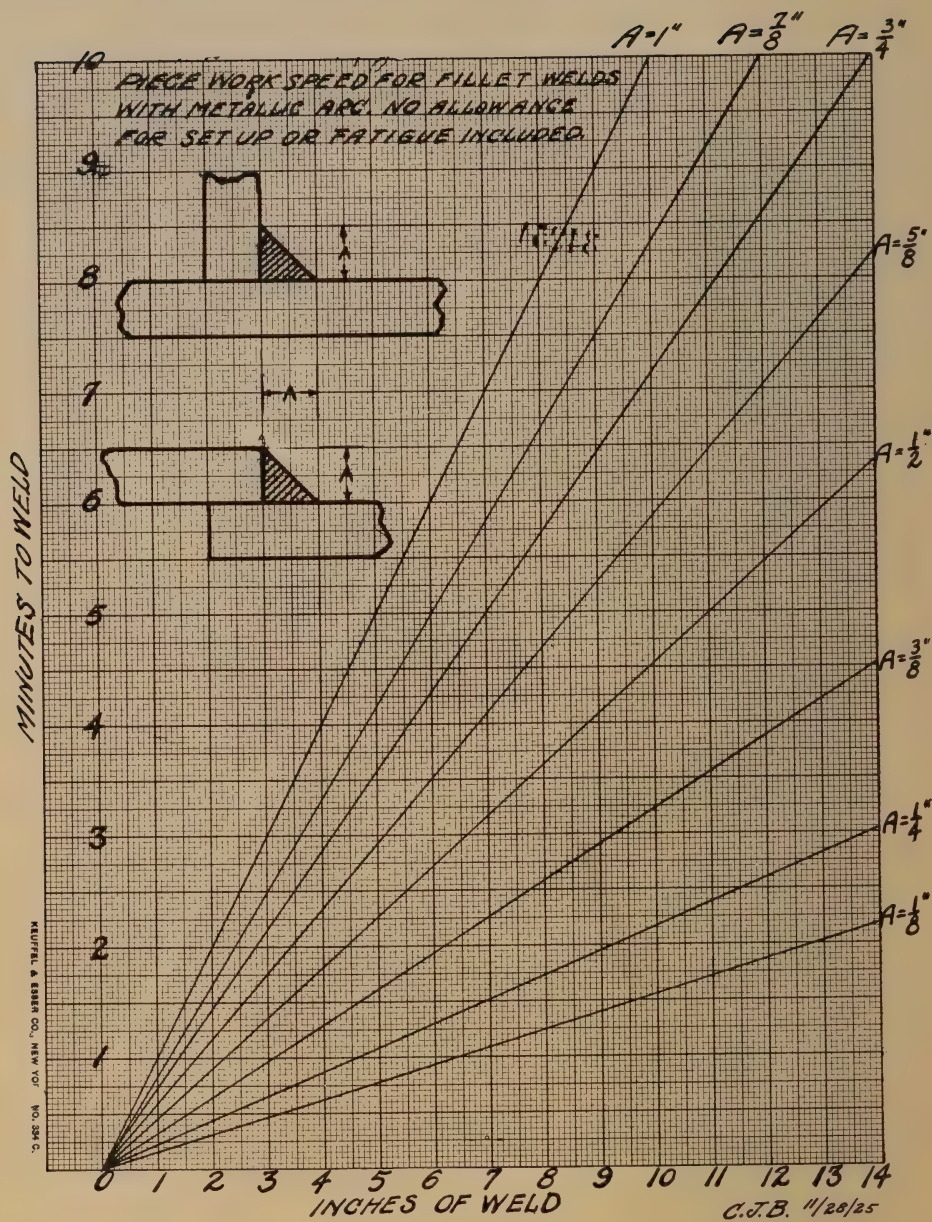


Fig. 199

Piece work speed for horizontal fillet welds with metallic arc. No allowance for set up or fatigue included.

Cost of Arc Welding Compared to Other Methods of Joining Metal

The chart reproduced in figure 198 shows the relative cost of joints, single riveted, double riveted, gas welded and arc welded. The cost is given in dollars per foot of seam for metal of various thickness from $\frac{1}{8}$ inch to 1 inch. It will be seen, throughout the entire range, arc welding is the least expensive process. The costs given on this chart (Fig. 198, page 123) are direct costs and do not include any charge for depreciation or upkeep.

Gas welding is frequently used in repair shops where welding is incidental to the general repair business. This is because the first cost of equipment for gas welding is less than the cost of an arc welder. While the investment in an arc welder is not large (usually less than \$1000) it is still an item for the small shop.

However, when the amount of welding is more than three linear feet of weld per day, arc welding is more economical than gas welding. This is shown graphically by the chart reproduced in figure 200. On this chart is a curve showing the fixed charge at 17 cents per day. A second curve shows the daily cost of gas welding with the fixed charge reduced to zero. That is, it is assumed that the equipment for gas welding cost the user nothing. The fixed charge for the arc welder is taken at 60 cents per day. Even on this basis it will be seen that arc welding is far less expensive for production welding.

The chart figure 198, showing the cost of arc welding per foot of seam for various thicknesses of metal, is sufficiently accurate for purposes of comparison. It is, however, not suitable for estimating purposes.

DAILY COST

\$ 300

2.75

2.50

2.25

2.00

1.75

1.50

1.25

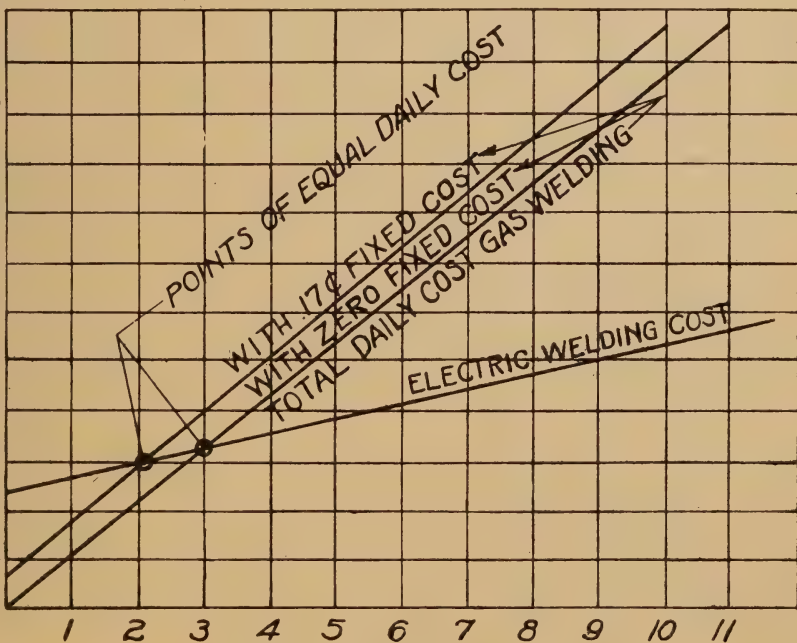
1.00

.75

.50

.25

0



Feet of $\frac{1}{4}$ " weld per day.

Fig. 200. Daily cost of operating a gas welder and an arc welder. Gas welding costs shown both with and without fixed charges.

PIECE WORK SPEED FOR FILLET WELDS WITH METALLIC ARC. NO ALLOWANCE FOR SET UP OR FATIGUE INCLUDED.

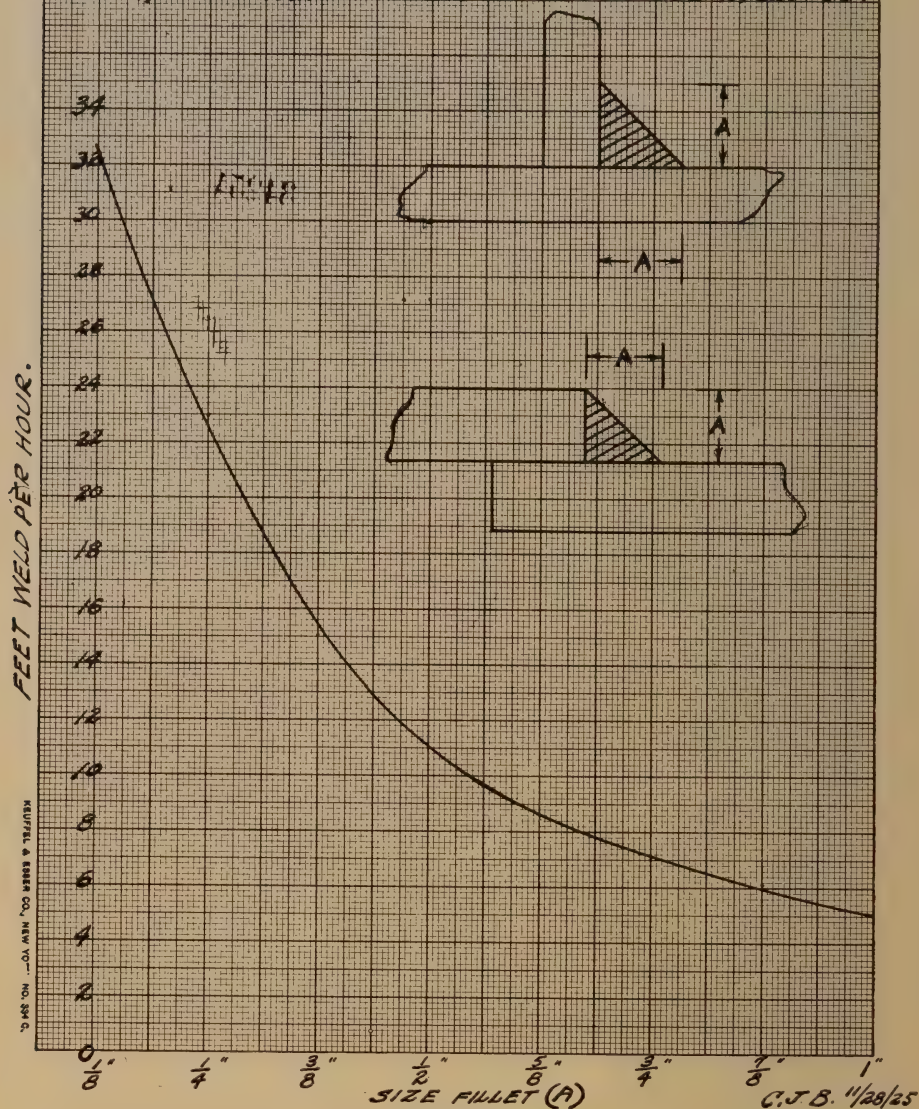


Fig. 201

Piece work speed for horizontal fillet welds with metallic arc. No allowance for set up or fatigue included.

The Speed of Welding

It is important to know that the speed of welding and consequently the cost of any job can be estimated in advance with the same degree of accuracy that the cost of any machining operation can be estimated. Most production welding is done on a piece-work basis and the problem of determining rates for any kind of welding becomes very simple when the principles are understood. The following paragraphs give the theory of determining welding speeds:

The time required to make a weld varies directly with the rate at

which the metal is melted.

It is therefore necessary, first, to know the rate at which an arc welder will deposit metal. This is found by reference to a curve such as is reproduced in figure 202.*

The nature of the weld determines the size of the electrode and also the proper current to be used. Knowing these, the amount of metal deposited per hour is read directly from the curve.

Divide the amount of metal to be deposited (in pounds) by the rate of deposition and the result is the time required to make the weld.

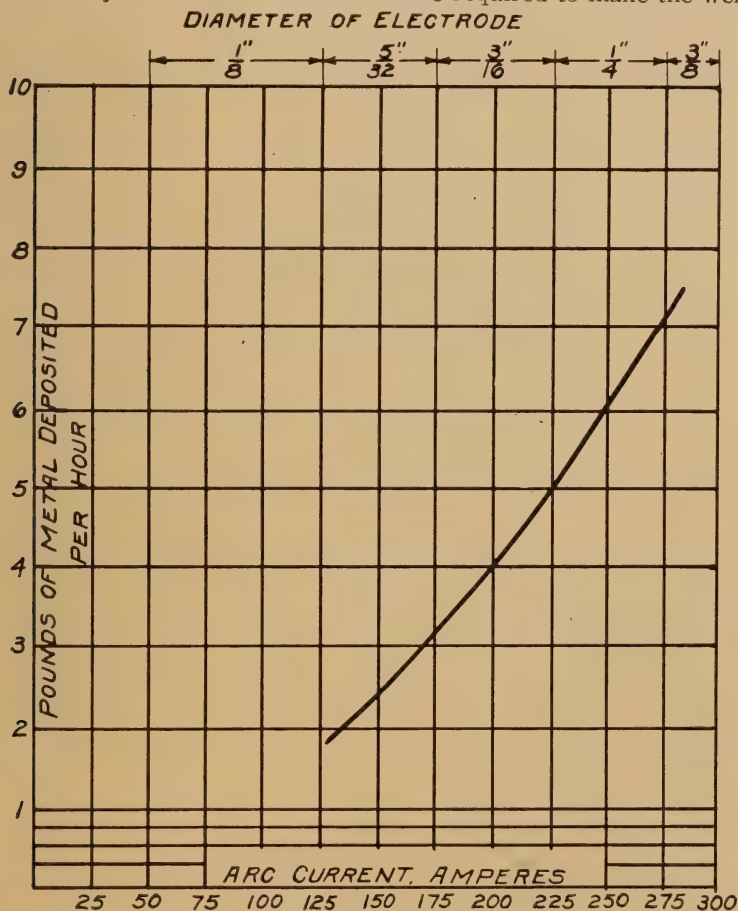


Fig. 202

Pounds of metal deposited per hour by metallic arc.

*NOTE—The rate at which metal is deposited is not the same for all makes of arc welders. The curve reproduced in figure 202 shows the rate of deposition for the Lincoln Stable-Arc Welder manufactured by The Lincoln Electric Co. It should not be used in computing the speed of welding with any other make of arc welder as all arc welders are not equally efficient.

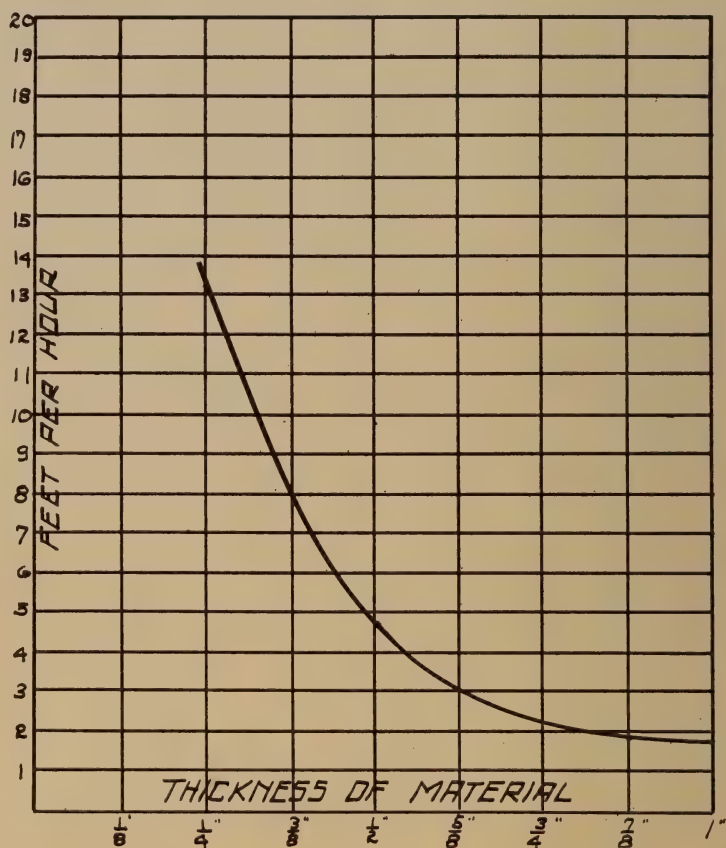


Fig. 203
 Piece work speed of welding 60° double bevel. Metallic arc.

Curves Showing Speed of Welding

In practice it is usually not necessary to go through all of this computation to determine the speed of welding as the figures have been worked out for all typical welds. Curves reproduced in this chapter show the speed of welding for various styles of welds. The time required to make any ordinary weld can be read directly from these curves.*

No allowance is made for set up

time or for fatigue of operator in these curves. Naturally the time which the operator is actually depositing metal will vary with the nature of the work. An average would probably be about sixty per cent.

The person in charge of piece work rates will quickly learn what percentage of actual operation can be expected for different classes of work.

*NOTE—These curves are based on the rate at which The Lincoln Stable-Arc Welder will deposit metal and will be found very accurate for determining welding speeds with that machine. These curves should not be used in determining the speed of welding with other machines for reasons explained in the previous foot note.

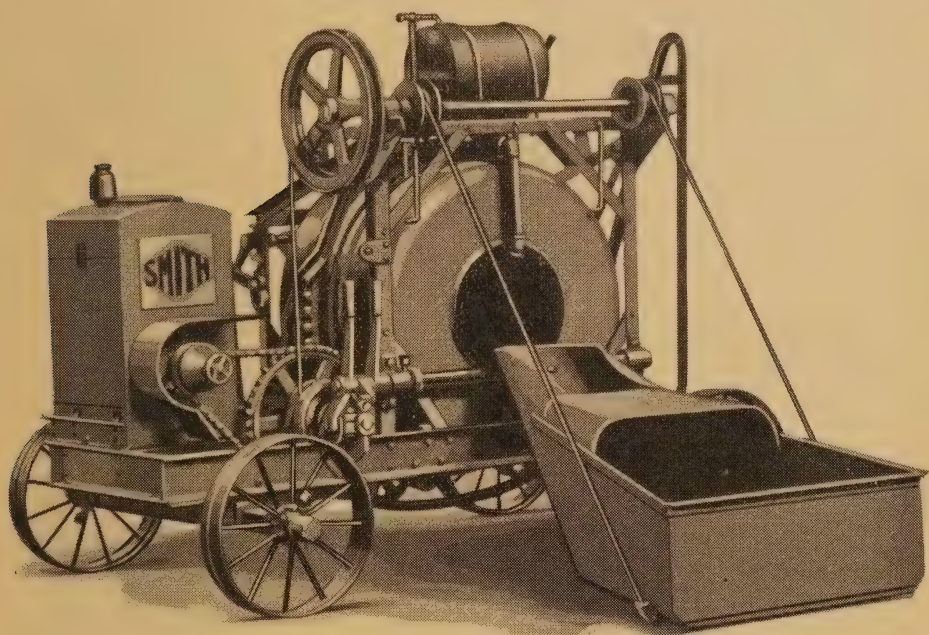


Fig. 204

Eight and three-quarter hours were required to rivet the drum on this concrete mixer. It is now arc welded in five hours. This is one of many applications of arc welding made by The T. L. Smith Co., Milwaukee, Wis.

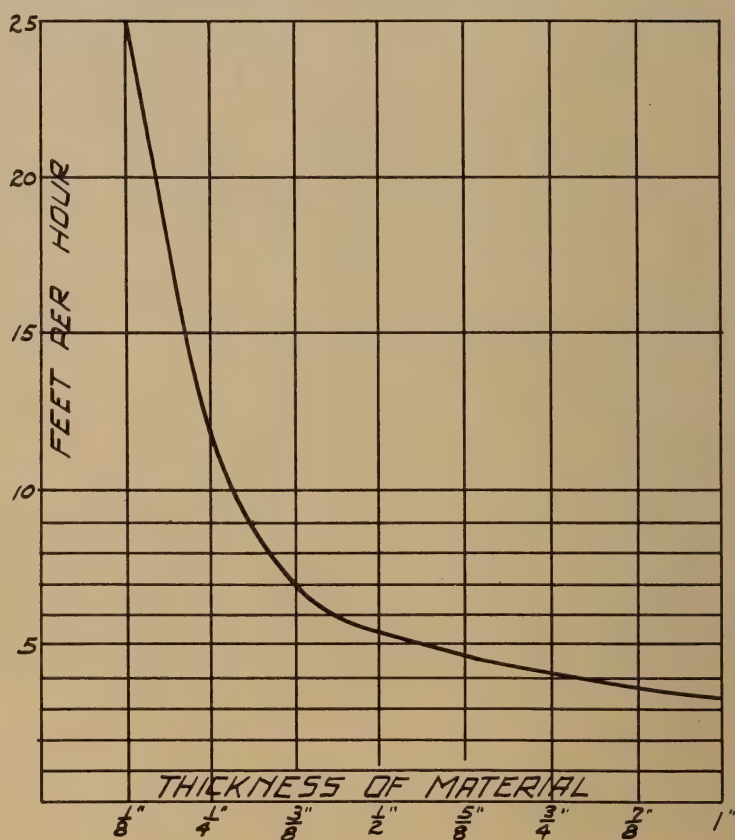
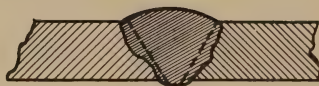


Fig. 205

Piece work speed of welding 60° single bevel. Metallic arc.

The Cost of Welding

The cost of welding is found by multiplying the time required to make the weld by the hourly rate. The hourly rate includes:

Cost of labor.

Cost of welding wire.

Cost of current.

The cost of labor is the largest item for all classes of welding. Rates vary widely but the rate of 80 cents per hour is assumed for this discussion.

The cost of welding wire is the next largest item. This varies directly with the amount of metal deposited. When welding continuously a welder operating at 250 amperes, with $\frac{1}{4}$ inch electrode, will deposit about $6\frac{1}{4}$ lbs. of metal per hour. This figure should be increased by 20% to cover waste, making the amount of welding wire required for *continuous operation*, $7\frac{1}{2}$ lbs. per hour. At 8 cents per pound, the cost of welding wire would be 60 cents per hour.

In actual practice the welder will not be in continuous operation.

Some time must be allowed for setting up work and for fatigue of operator. Assuming that the welder is in actual operation 60% of the time, the cost for welding wire will be 36 cents per hour.

The cost of current is the smallest item. This cost varies with the power rate per K. W. H., and the percentage of time that the welder is in actual operation. Assuming a power rate of 2 cents per K. W. H., the cost of power for *continuous operation*, will be approximately 13 cents per hour. The sum of these items gives an hourly rate of \$1.29 for 60% operation.

Sixty per cent operation was chosen for the discussion above because it represents average conditions. There will frequently be cases where the percentage of operation will be much higher than this. When this is true, the hourly rate will increase slightly as more welding wire and more power will be required.

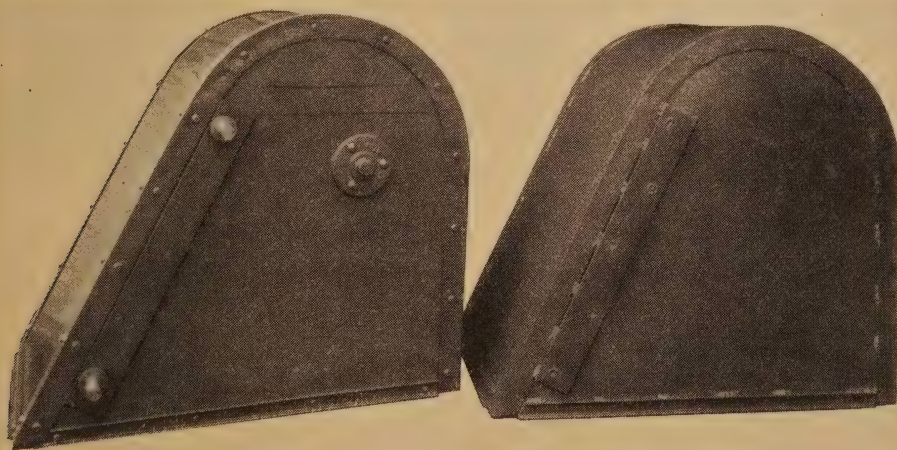


Fig. 206

Eight hours were required to drill, fit up and rivet the load bucket illustrated on the left. The welded bucket was completed in $4\frac{1}{2}$ hours,—a net saving of $3\frac{1}{2}$ hours. Photographs and data furnished by the W. E. Dunn Mfg. Co., Grand Rapids, Mich.

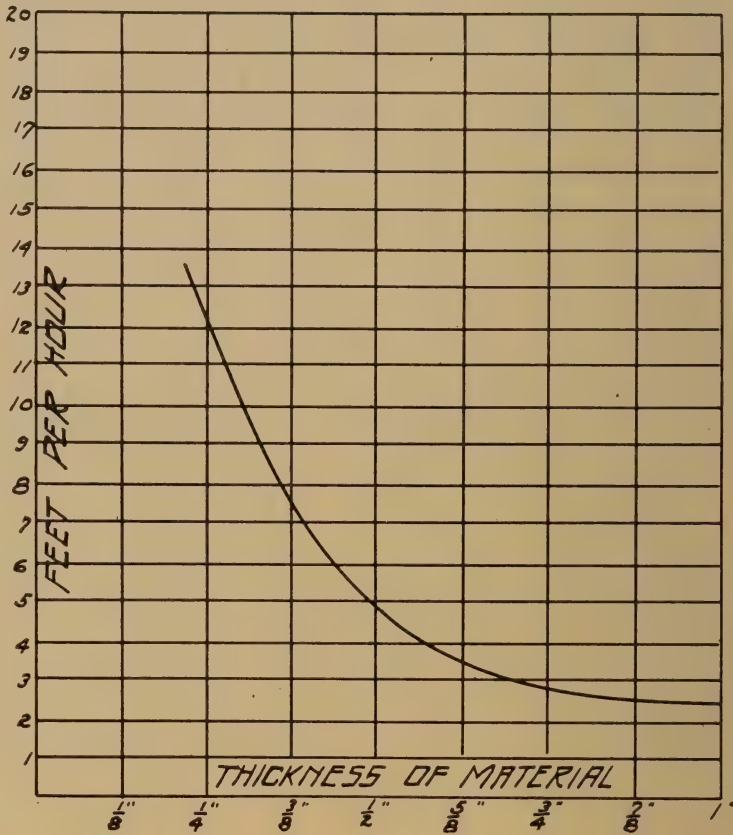
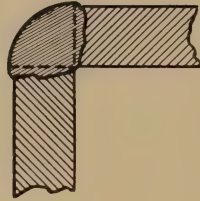


Fig. 207

Piece work speed of welding 90° corner weld. Metallic arc.

Overhead

The overhead cost includes the same elements of first cost of equipment, cost of floor space, light, heat, etc., that are figured for any other production tool. There is usually a very great saving here. Since practically all factories are supplied with electricity, there is no space required

for auxiliary equipment such as air compressor, or gas generator, which are required for riveting or gas welding. The arc welder takes up very little space and in many plants is mounted on a portable truck and moved from place to place as the work requires.

Method of Figuring the Cost of a Typical Weld

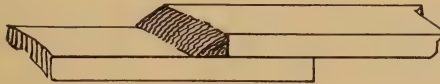


Fig. 208

PROBLEM

Figure cost to make a single lap-welded joint 72 inches long, between two plates $\frac{1}{2}$ inch thick.

First Step. Determine time required to make the weld, assuming continuous operation.

This is found by referring to the curves reproduced in figure 199. The curve for plates $\frac{1}{2}$ inch in thickness shows that to weld 12 inches of seam requires approximately $5\frac{1}{2}$ minutes.

To weld 72 inches, assuming continuous operation, will require $72/12 \times 5\frac{1}{2}$ or 33 minutes.

Second Step. Determine the percentage of time that the welder will actually be depositing metal.

This depends on set-up time, etc. For this example let us assume 60% operation.

The total elapsed time will then be: $33 \times 100/60$ or 55 minutes.

Third Step. Compute cost of the weld.

Since the hourly rate for an arc welder for 60% operation is \$1.29, the cost of making the weld described above is: $\$1.29 \times 55/60 = \$1.18$.



Fig. 209

The old tradition that steel pipe would not last underground has been effectually killed. Today, by far the greatest amount of land pipe is made of steel. Steel pipe is made most economically on automatic arc welders. Here is a stack of 20" diameter pipe arc welded by The Lancaster Iron Works, Lancaster, Pa.

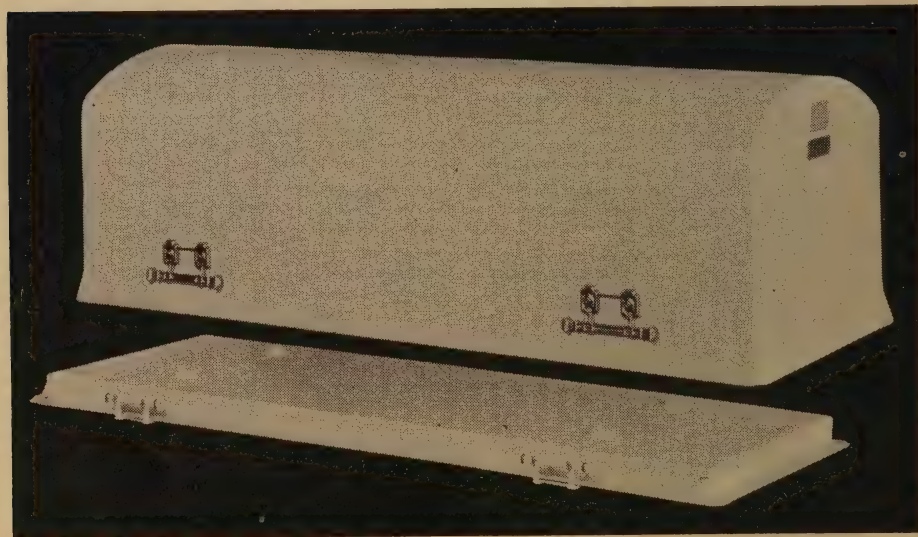


Fig. 210

The National Grave Vault Co. gives three reasons for substituting arc welding for riveting in the manufacture of grave vaults. They are: More permanent construction, better appearance, and lower costs. This company was among the first to adopt automatic welding.

CHAPTER VII

Automatic Arc Welding

THE automatic arc welder is literally a sewing machine for steel. By this remarkable machine the edges of two pieces of steel plate can be joined with the same facility that a seamstress joins the edges of two pieces of silk.

In automatic arc welding the edges of the plates to be welded are held firmly in the proper position for welding by a jig or fixture. The electrode forming one end of the arc is moved automatically along the seam or the work itself is moved past the electrode at the proper speed to insure a perfect weld. Provision is made for feeding down the

electrode, as it is consumed, at exactly the proper rate to maintain a steady uniform arc.

Once the correct speed of feeding has been determined it is only necessary to place the work in position and start the arc.

There is no more spectacular operation in the entire field of manufacturing. A machine which joins solid pieces of steel with a joint of equally solid steel, the entire process unaided by human hands, is a far cry from the old method of pegging steel together with rivets.

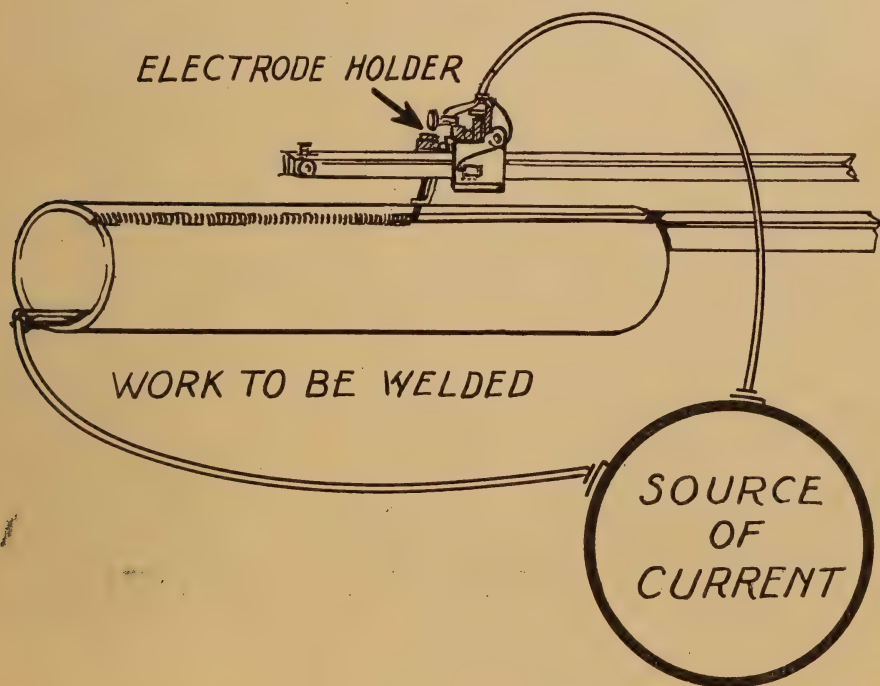


Fig. 211

Diagrammatic view of Automatic Welding Process.

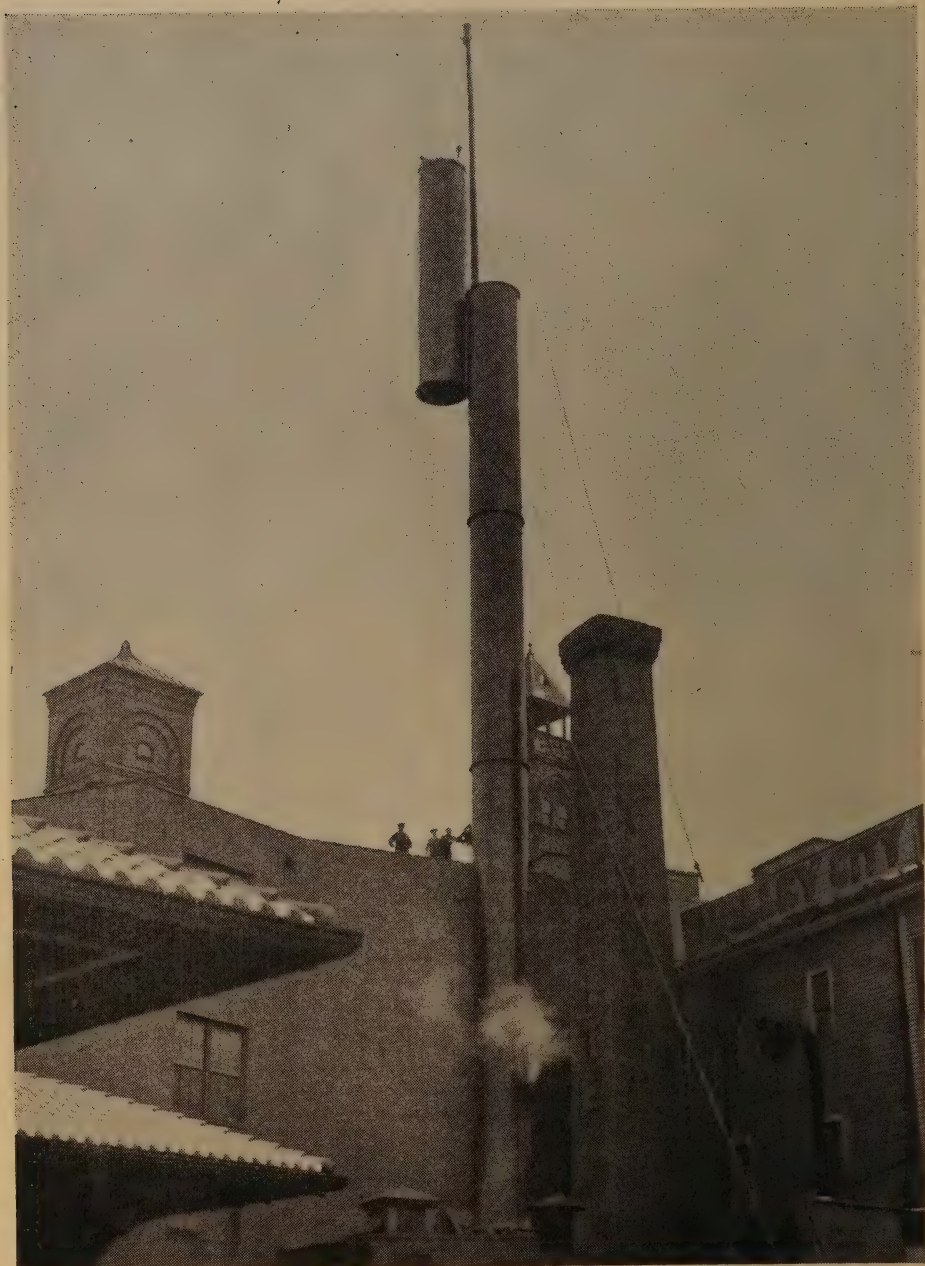


Fig. 212

There are no rivets to rust or corrode in this arc-welded stack, built by The Leitel Iron Works, Grand Rapids, Mich.

Field for Automatic Welding

The field for automatic welding is wherever similar steel parts are to be joined in production quantities. The shape of the product, the length of weld, the weight or thickness of the steel are of minor importance. If the quantities are sufficiently large, automatic welding will reduce the cost of making joints.

In addition to the obvious applications such as the manufacture of gasoline tanks, the automobile industry utilizes automatic welding in making rear axles, frames for self-starter motors and many other

products. Range boilers and grave vaults are welded automatically. Steel pipe up to 65 inches in diameter has been welded automatically with astounding savings. Crude oil storage tanks of large proportions are welded by a most ingenious self-propelled welding head which follows the seams with uncanny accuracy and joins each seam with a permanent leak-proof joint. If steel is to be joined to steel in production quantities, automatic welding should be investigated.

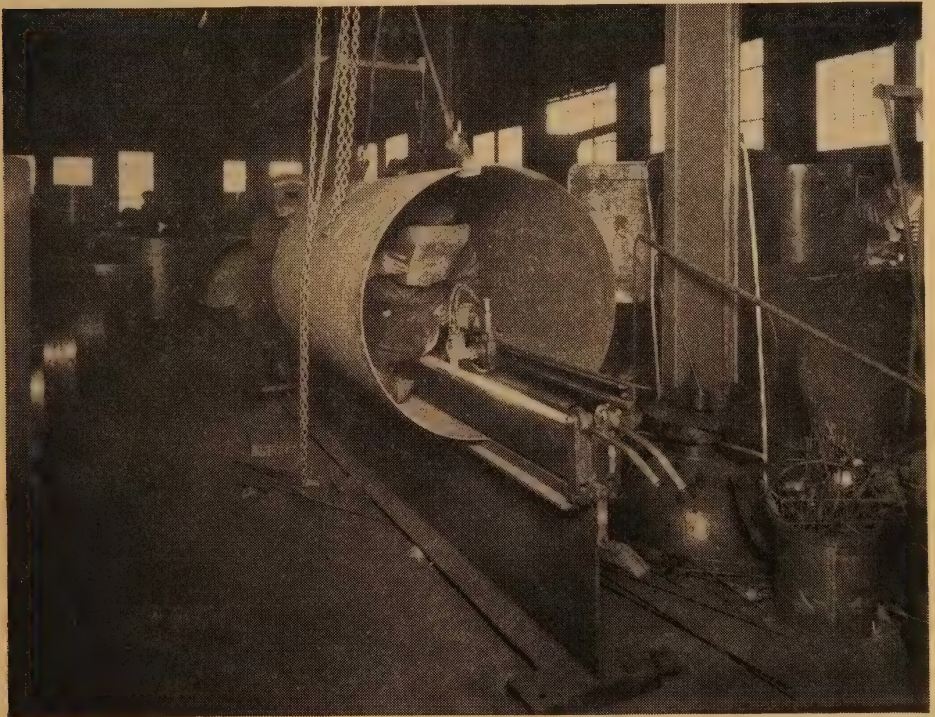


Fig. 213

Welding inside seam on small tank.

Table of Speeds and Costs of Automatic Electric Arc Welding



Joint Before Welding



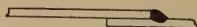
Joint After Welding

Data for Butt Weld (One Side Only)

Gauge of Material ...	18	16	14	12	10	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{1}{2}$ "	$\frac{5}{8}$	$\frac{3}{4}$
Speed in feet per hour	170	160	150	100	75	60	40	25	17 $\frac{1}{2}$	14	10
Current (Approx.) ...	275	300	325	350	375	400	450	550	650	700	750
Size Filler Rod (Approx.)	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{16} \times \frac{1}{2}$	$\frac{1}{4} \times \frac{5}{8}$	$\frac{5}{16} \times \frac{5}{8}$	$\frac{1}{2} \times \frac{3}{4}$
Size Carbon (Approx.)	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Total Cost per Foot...	\$.0097	.0110	.0119	.0187	.0252	.03	.048	.085	.1317	.170	.233



Joint Before Welding

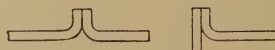


Joint After Welding

Data for Lap Weld

Gauge of Material.....	16	14	12	10	$\frac{3}{16}$	$\frac{1}{4}$
Speed in Foot per Hour.....	165	135	105	80	65	45
Current.....	250	275	300	325	350	400
Size Carbon.....	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{8}$
Total Cost per Foot.....	\$.0071	.0084	.0117	.0158	.0200	.0291

NOTE: On lap weld no filler rod is used.



Joint Before Welding



Joint After Welding

Data for Edge Weld

Gauge of Material.....	18	16	14	12
Speed in Foot per Hour.....	200	180	150	125
Current.....	180	200	225	250
Size Carbon.....	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$
Total Cost per Foot.....	\$.0055	.0062	.080	.096

NOTE: On edge weld no filler rod is used.

These costs include Power at 3c per K.W.H., Metal Electrode at 8c per pound, Carbon Electrode at 13c each, Labor at 60c per hour and cover welding time only.

Owing to varying conditions in different plants it is manifestly impossible to give actual costs, including set up time. If the work is properly organized the arc should be running 75 to 80 percent of the time.

The Automatic Welder Makes Perfect Welds

In quality of work the automatic welder equals or betters the work of the most experienced manual welder operator. The length of the arc and the rate of feeding are constant and the welds produced are uniform in strength and appearance.

The amount of current required for each job and consequently the amount of heat for perfect welds, can be determined once for all. An automatic welder can be set up for a particular job with the same degree of exactness that the indexing head on a milling machine can be set for cutting gears.

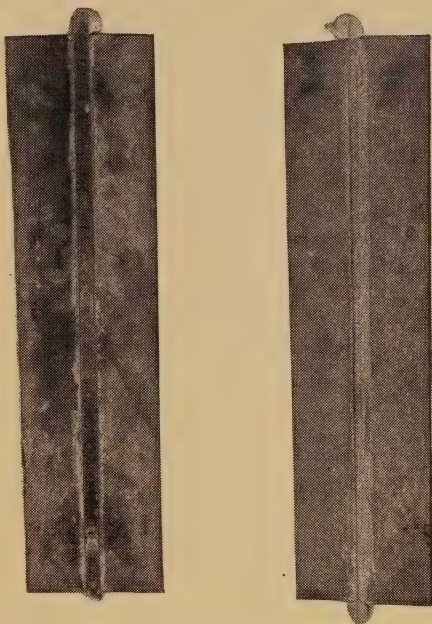


Fig. 215

Upper and lower side of seam made by automatic arc welder using carbon electrode. Note how the weld is reinforced on the under side. This is made possible by the use of copper strips which in effect form a mold for the molten metal.

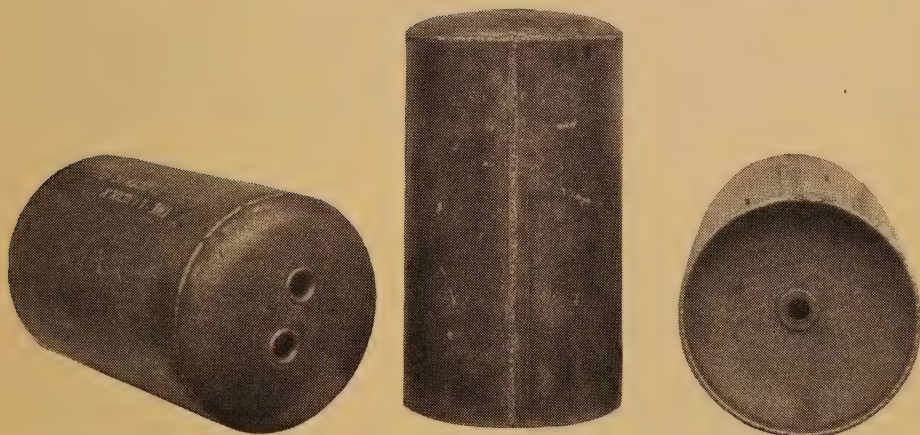


Fig. 216

Range boilers produced by Automatic Arc Welding. Note the edge welds on bottom.

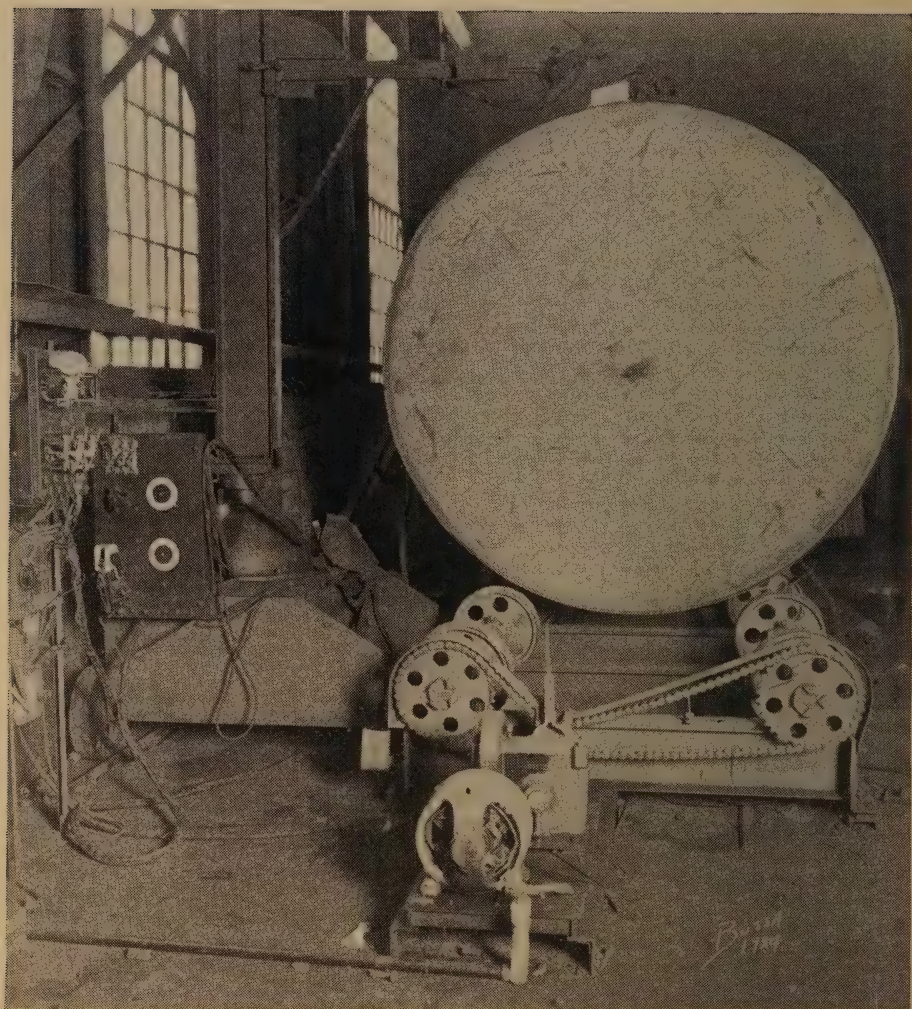


Fig. 217

Welding the girth seams on oil tank using a rotating fixture.

Speed of Automatic Welding

An automatic welder never tires. This is one reason for the greater welding speeds obtained by automatic welding over manual welding. The speed of feed can be adjusted for maximum production and this speed can be maintained without in-

terruption. This, however, is not the only factor which accounts for the high speeds possible in automatic welding. The greatest factor is the utilization of the carbon electrode arc instead of the metallic electrode.



Fig. 218. Automatic welding on gravevaults.

Carbon Electrodes Are Used for Automatic Welding

The most successful automatic welders utilize the carbon electrode process. As explained in Chapter III, this is a puddling process and not a deposition process. The heat of the arc melts the edges to be joined and where additional metal is required it is supplied by a filler rod which is laid along the seam prior to welding. The small pool of molten metal underneath the arc is kept in bounds by water-cooled copper strips which in effect form a mold.

The edges of the plates to be joined and the metal supplied by the filler rod are melted simultaneously

and as the arc moves along the seam this molten pool cools and solidifies, forming a solid homogeneous weld. By this process oxidation is at a minimum because only the very small surface of the molten metal is in contact with the air.

Since the edges of the plates and the metal added by the filler rod are in the molten state at the same instant and cool at the same time there is no possibility of laps or seams by this process.

With a carbon electrode there is no limit to the amount of current

that can be used. With a metallic electrode there is a very definite limit to the amount of current. This limit is the amount of heat which the tip of the electrode itself will stand. Obviously if it were attempted to put a very large current through a small metallic electrode the electrode would burn up almost instantaneously.

Even with the comparatively small currents suitable for welding on light material the problem of feeding metallic electrodes is much more difficult than the feeding of carbon electrodes. A much finer adjustment is necessary, requiring intricate mechanism which is not required on a carbon electrode welder.

Automatic welding with the carbon arc is more economical than with the metallic arc for two reasons. First the speed of welding is greater, and second, the cost of filler metal is less with the carbon arc process.

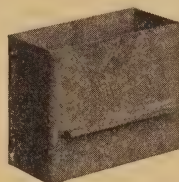
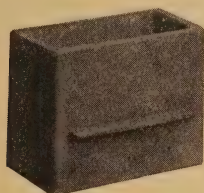
The speed of welding is greater because more heat can be utilized at the arc which means that metal is melted faster.

The cost of filler rod is less because a smaller amount is used and also because the cost per lb. of the mild steel rod or strip which is generally used in carbon arc welding is less than the cost per lb. of the specially prepared wire which must be used in the metallic arc process.



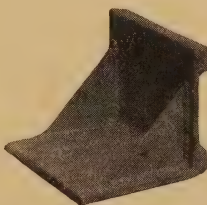
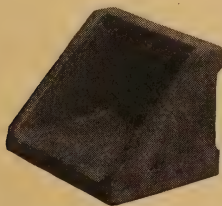
Twelve Inch Pulley

		Weight			Cost	
Cast Iron	-----	79 lbs.	Material	-----	\$7.90	
			Labor	-----	2.99	\$10.89
Steel	-----	14 lbs.	Material	-----	\$1.20	
			Labor	-----	1.85	3.05



Wall Box

		Weight			Cost	
Cast Iron	-----	35 lbs.				\$2.10
Steel	-----	14 lbs.	Material	-----	\$.42	
			Labor	-----	.30	.72



Support

		Weight			Cost	
Cast Iron	-----	27 lbs.				\$2.27
Steel	-----	14 lbs.	Material	-----	\$.42	
			Labor	-----	.23	.65

Fig. 219

Striking examples of the substitution of arc welded steel for cast iron. The Baker-Perkins Company, Saginaw, Michigan, who developed these applications supplied the cost figures.



Fig. 220

Spherical tank in course of erection by the Chicago Bridge and Iron Works, fabricators of Horton Steel Tanks. This "Hortonsphere" is arc welded throughout, making it the most economical as well as the strongest type of storage tank that can be designed.



Fig. 221

Mast head fittings built by the Chicago Bridge and Iron Works for use in connection with erecting "Hortonspheres."

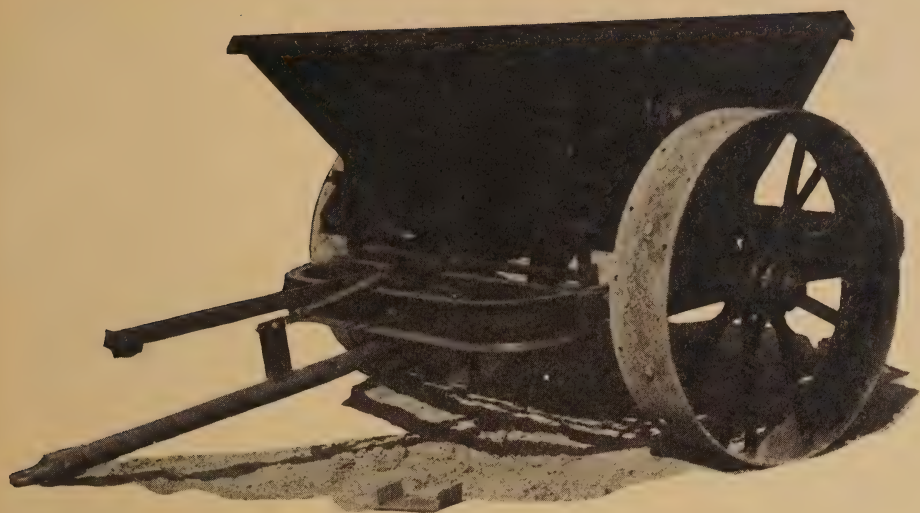


Fig. 222

Dump cart arc welded by the Euclid Crane & Hoist Company, Euclid, Ohio.
All permanent joints are arc welded.



Fig. 223

Wrought iron doors in the home of Harry K. Thaw, Pittsburgh, Penna., arc welded by the Jansen Art Forging Company, Cuyahoga Falls, Ohio. Arc welding effects great economies in the manufacture of ornamental iron work.



Fig. 224

Electric heater arc welded by Littleford Bros., Cincinnati, Ohio.



Fig. 225

The Detroit Stoker, Detroit, Michigan, have cut manufacturing costs to a minimum by arc welding. Coal hoppers, drive chain guards and trench floor plate frames are among welded parts shown in this photograph.

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ADVERTISING SECTION

The Equipment for Arc Welding

ALL of the welding on the various products illustrated in this manual was done by the Stable Arc Welder, manufactured by The Lincoln Electric Company. The Stable-Arc Welder is built in a complete range of sizes and styles to provide for any class of work and any operating conditions.

All of these types consist essentially of:

1. A standard motor driven by the shop power lines. (This motor

furnishes the power for driving the welding generator. Where electric power is not available, gasoline engine or belt driven welders are supplied.)

2. A specially wound generator delivering current at the proper voltage for welding.

3. A stabilizer acting as a reservoir of current.

4. A control panel with simple knife switches and meters for adjusting the amount of welding heat.

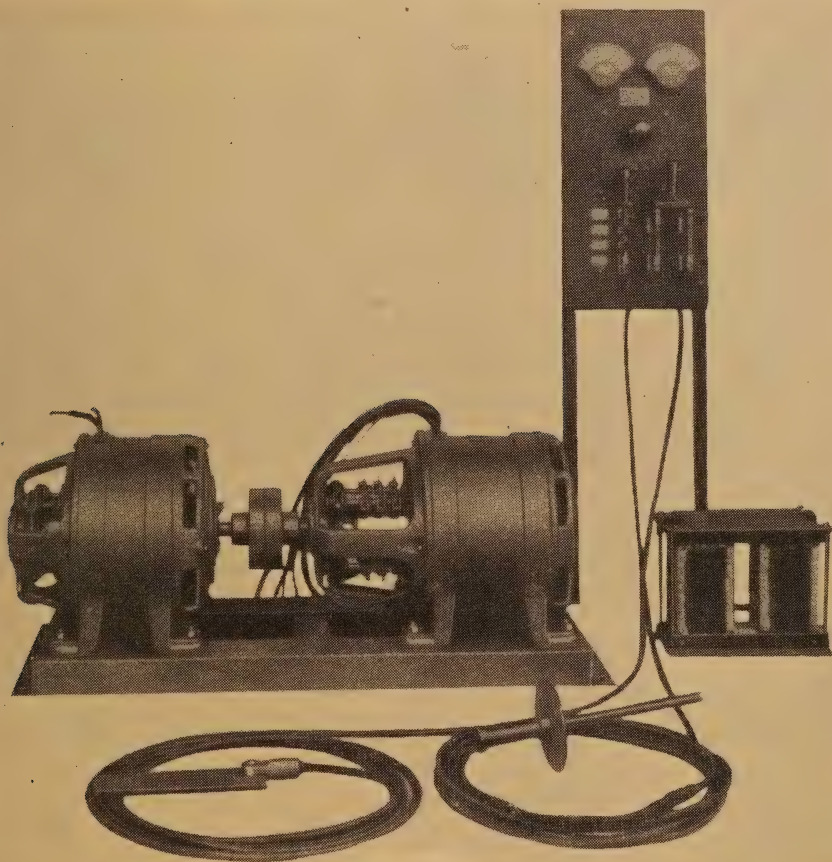


Fig. 226

Stationary panel type. As built in the larger sizes.

The Stable-Arc Generator

The design and construction of the welding generator partly accounts for the uninterrupted flow of heat which is possible with the Stable-Arc Welder. This generator is wound with what is termed a bucking series field which with the laminated steel frame produces a welding current with the proper characteristics described in the previous chapter.

Not only the pole pieces but the complete magnetic circuit of the Stable-Arc Welder is laminated, that is, built up of steel laminations or sheets. The electrician will readily understand that this type of construction permits a very rapid change in the magnetism or "flux density" and this in turn makes it possible for the electric current to adjust itself instantly to any demand.

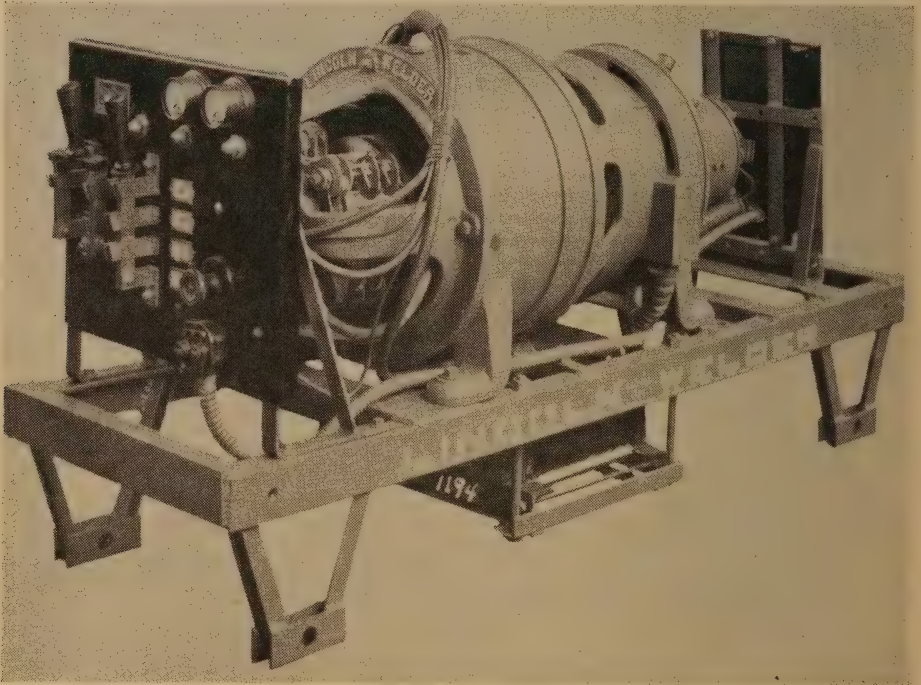


Fig. 227

Stationary platform type. Built in 200 and 300 ampere sizes.

The Stabilizer

In addition to the laminated steel generator the Stable-Arc Welder is provided with a stabilizer which, in electrical terms, is simply an inductance in the welding circuit. This stabilizer acts on the electric current much like a flywheel does on any other piece of machinery. It stores up energy which permits the machine to take care of extraordinary demand without difficulty.

A Steady Arc Means Good Welds

Because of the laminated frame construction and stabilizer, the Stable-Arc Welder produces an arc which is steady and easy to maintain. This means better and faster welding. Frequent breaking of the arc and the necessity of frequent starting produce a brittle and porous condition in the weld. The best welds are made where the arc is kept steadily in operation and the metal thus deposited is homogeneous and strong.

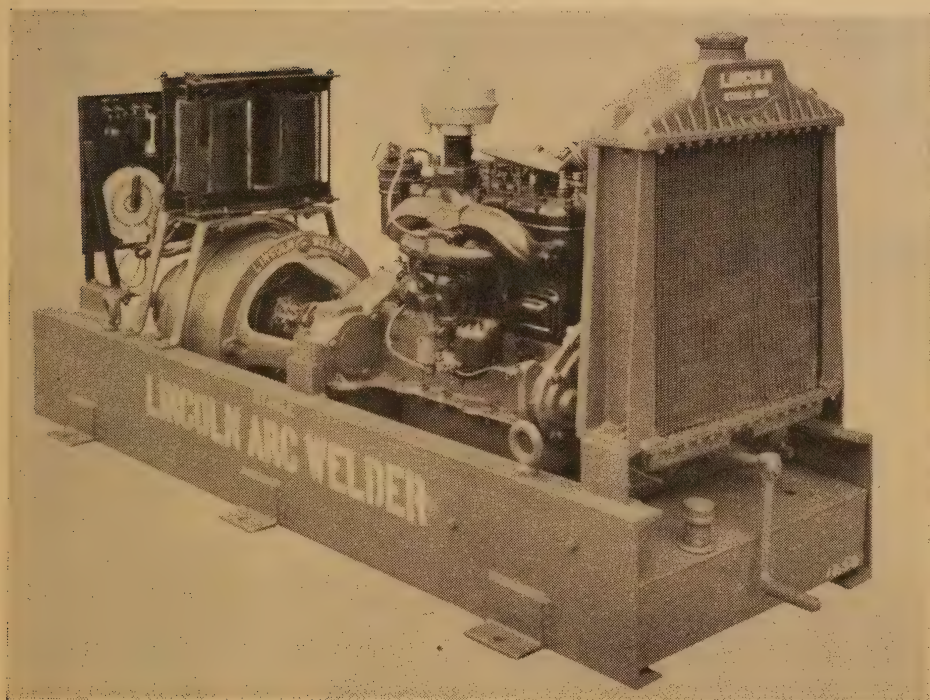


Fig. 228

Gasoline engine driven type. Built in 200 and 300 ampere sizes.

Methods of Driving the Welding Generator

The Stable-Arc Welder can be operated by any of the following means:

1. An electric motor operating on either direct or alternating current of any standard voltage.
2. A gasoline engine direct connected to the welder.

3. Belt drive.

In the majority of cases electric current is available wherever welding is to be done. This is the most satisfactory and economical method of operating the welder.

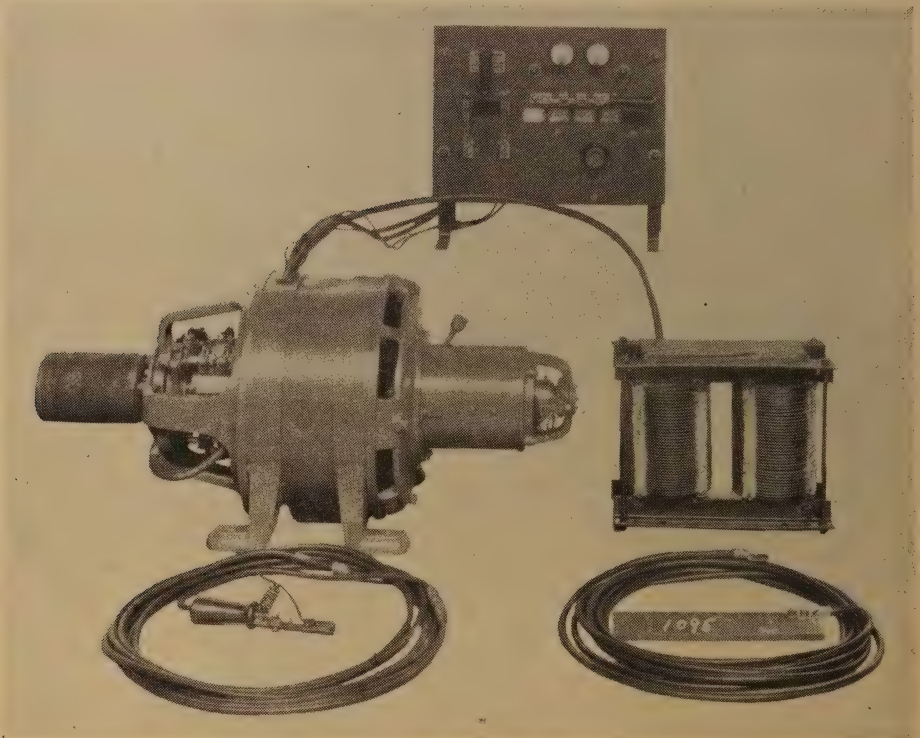


Fig. 229

Belted type. Built in all sizes.

Types of Stable-Arc Welders

Stable-Arc Welders are built in sizes of 200 amperes to 1200 amperes, rated in accordance with the standards of The Electric Power Club. They are mounted in various different ways to suit different operating conditions.

The various types are:

1. Stationary Platform Type.

This type is built in 200 and 300 ampere sizes. The entire equipment is mounted on a structural steel base and is furnished completely wired and ready for operation.

2. Portable Truck Type.

This type is built in 200, 300 and 400 ampere sizes. The entire equipment is mounted on an all-steel truck which can readily be moved to the work. This type is also completely wired and ready for immediate use.

3. Belt Driven Type.

This unit is built in all sizes. The equipment consists of generator, stabilizer, control panel, and necessary wiring. The driving motor is omitted. A pulley mounted on the shaft of the generator permits driving from the countershafting.

4. Gasoline Engine Driven Type.

This unit is built in 200 and 300 ampere sizes. A 4-cylinder heavy-duty engine is direct connected to the welding generator by a large flexible coupling. The entire equipment is mounted on a rigid arc-welded steel base.

5. Stationary Panel Type.

This unit is built only in the larger sizes. The motor and generator are mounted on a steel base. The control panel and stabilizer are separate and can be placed in the most convenient location for production work.

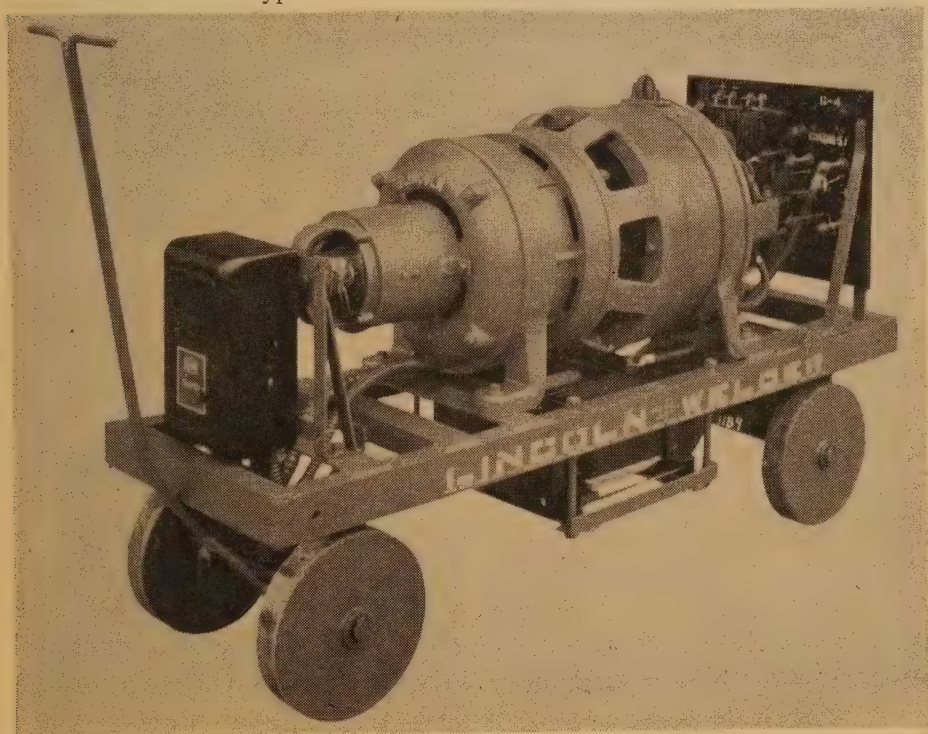


Fig. 230
Portable truck type. Built in all sizes.

Automatic Stable-Arc Welders

Automatic Stable-Arc Welders have been built in a wide variety of forms for highly special products. To describe all of these would unnecessarily complicate this work. All forms consist fundamentally of the following items:

1. Fixture for holding work in place. These fixtures generally constitute the base of the automatic welder serving to support the electrode holder and the feeding mechanism.

2. Device for moving the arc along the seam. In some types of automatic welders the arc is moved along the work and in other types

the work itself is moved. In every case there is provision for accurately controlling the speed of the feed by a small variable-speed electric motor.

3. Automatic electrode holder. This holder automatically feeds the electrode down as it is burned away in welding and maintains the arc at the proper length.

4. Source of welding current. A standard Stable-Arc Welder set furnishes the power for the automatic welders. The steady uninterrupted flow of heat which is delivered by these machines accounts for the remarkable output made on Lincoln Automatic Welders.

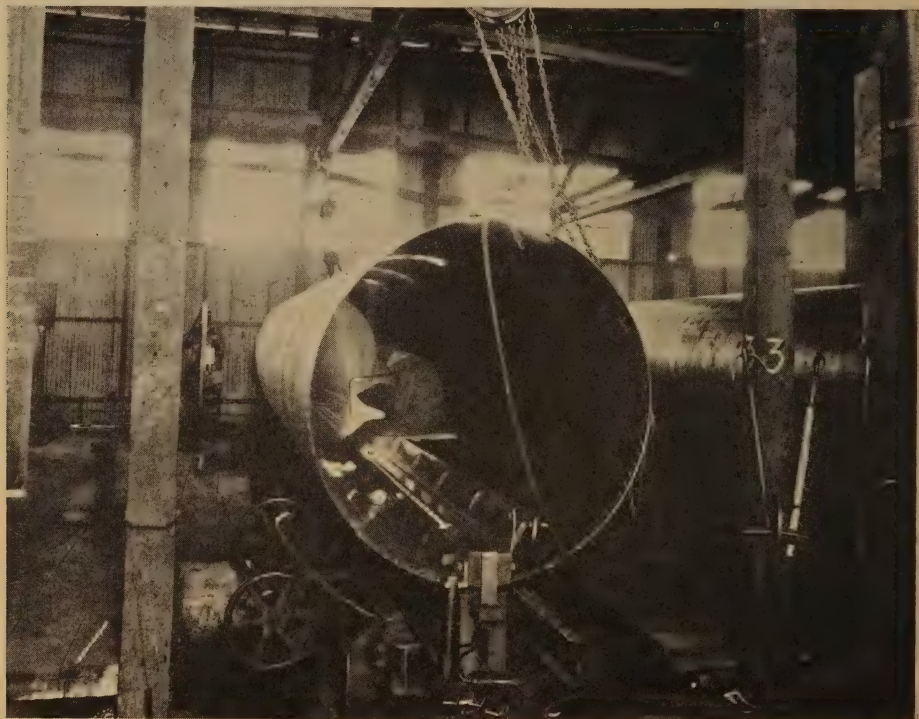


Fig. 231

Welding longitudinal seams on steel pipe at the Steel Tank and Pipe Company, West Berkeley, Calif. Pipe sections are 30 feet long and range from 48 to 60 inches in dia.

Types of Automatic Stable-Arc Welders

Horn Type

The Horn or Mandrel type is illustrated in figure 232. This machine welds outside longitudinal seams for cylindrical work such as range boilers, steel barrels, pipe, etc. Steel plate is rolled into shape and the edges to be welded are held rigidly in place by clamps. The lower clamp is a part of the base of the machine. The upper clamp is

operated either manually or by means of compressed air.

The welding head is driven along a horizontal arm by means of a small variable-speed electric motor. This welding head carries a mechanism for feeding down the electrode as it is consumed.

Welders of this type are built in lengths of 4, 8, 12, 16 and 20 feet.

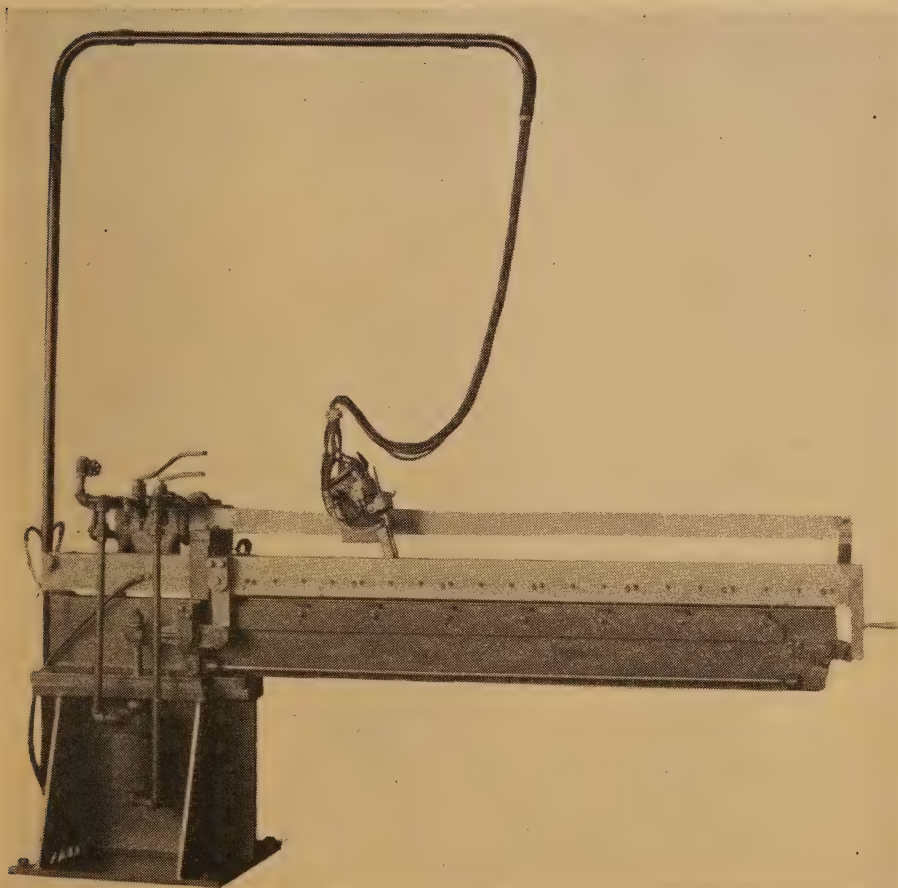


Fig. 232

HORN TYPE OUTSIDE SEAM WELDER

This type is used for welding the longitudinal seams on range boilers, tanks, barrels, pipe, etc. It is built in lengths of 4, 8, 12, 16 and 20 feet.

Base Type

Figure 233 illustrates the Base Type Inside Seam Welder. This machine is used for welding large pipe or tanks. The operation of this machine is identical with that of the Horn Type except that here welds are made on the inside. Because of the large size of the work handled, the holding clamps are operated hydraulically. The Base Type Welder is built in lengths of 20, 24 and 30 feet. It will handle pipe 40 inches in diameter and up.

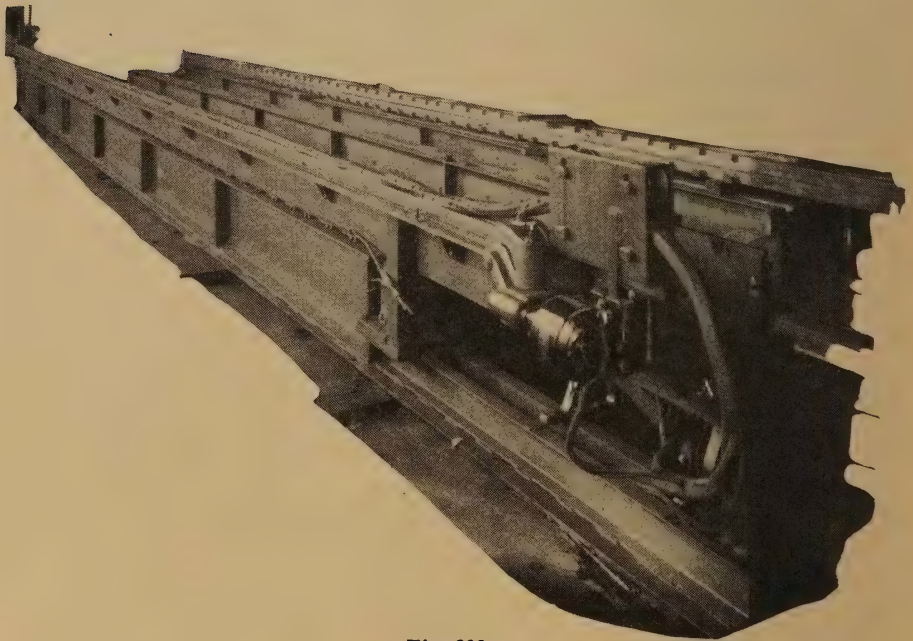
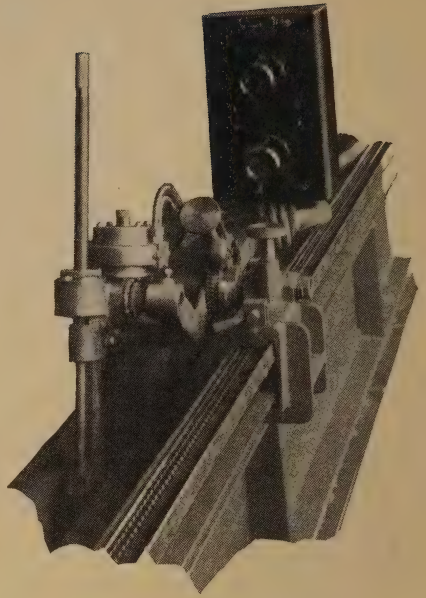


Fig. 233

Base type inside seam welder. This type is made in lengths of 20, 24 and 30 feet. It will weld pipe 40" in diameter and up.

Head Welder

The Head Welder, illustrated in figure 234, is used extensively for bottoming range boilers, steel barrels and small tanks. The welder makes what is known as an edge weld, no filler rod being required. The work to be welded is mounted on a ball

bearing rotating table. The welding head is carried by a horizontal arm supported by a vertical column. Provision is made for varying the speed of rotation of the table by varying the speed of the motor and by gear changes.

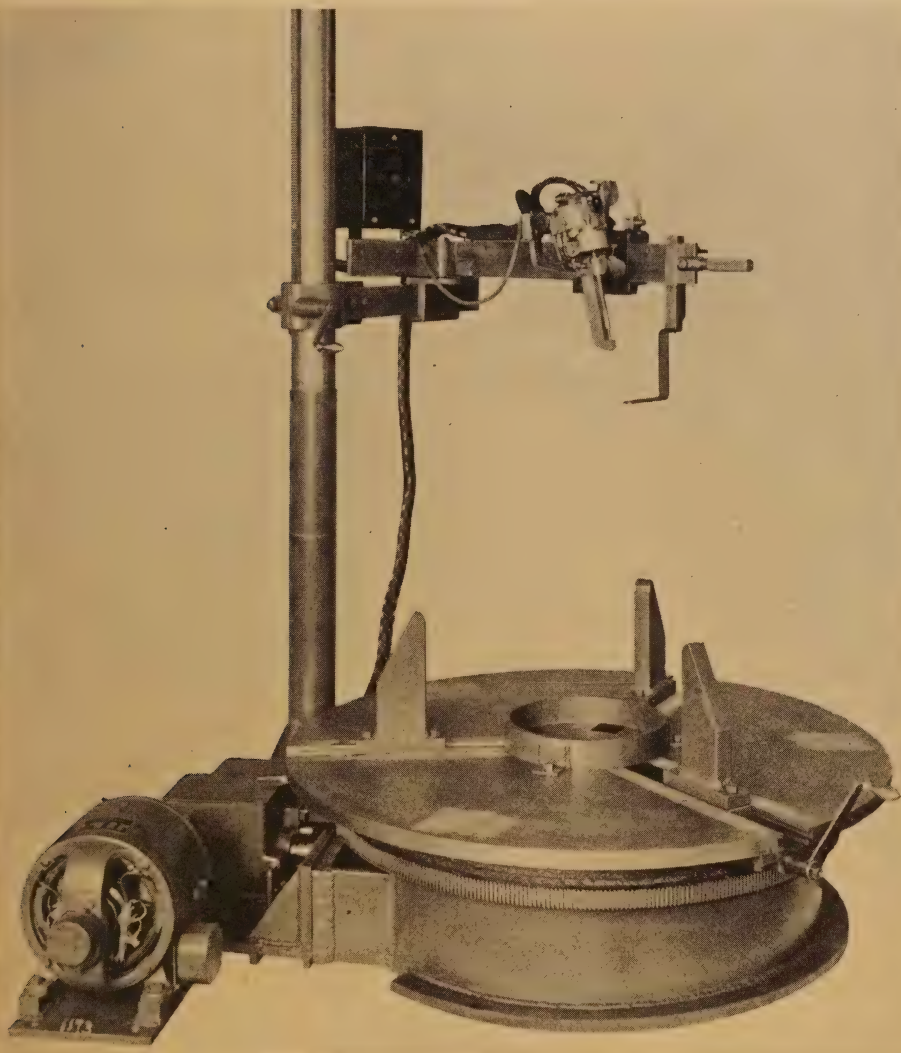


Fig. 234

Head Welder. This type is used extensively for bottoming range boilers, tanks, etc. It makes an edge weld requiring no filler rod.

Girth Welder

The Girth Welder, illustrated in figure 235, consists of a rotating fixture and a stationary support for the welding head. The set up tank is mounted on the rotating fixture and the arc started. Provision is

made for controlling the speed of rotation to obtain the proper speed of welding. Where it is desired to weld inside seams the Tractor Type of automatic is used as described on next page.

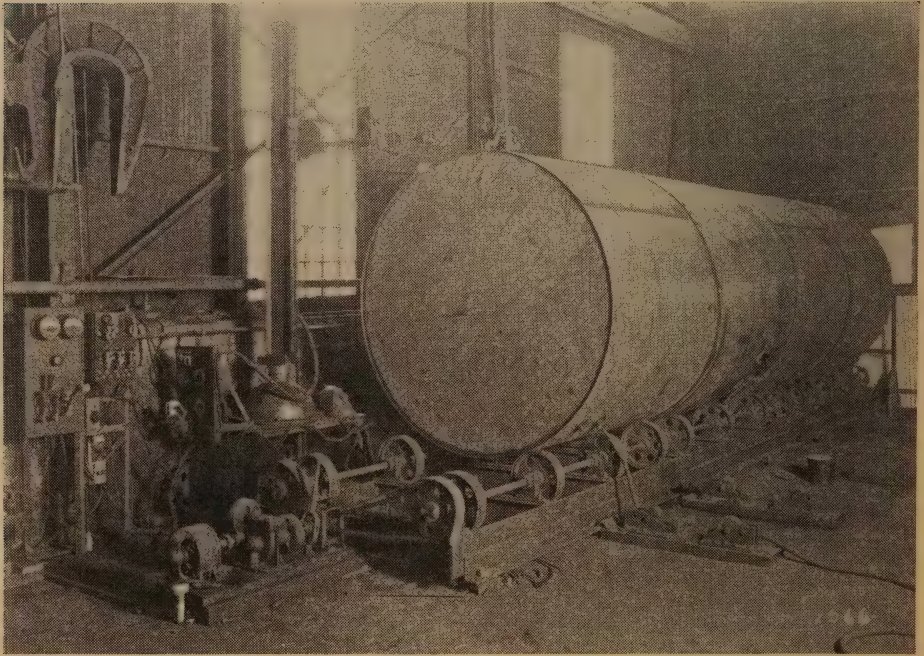


Fig. 235

Girth Welder. This machine is used for welding the girth seams of large tanks. The tanks are first tack welded and then placed on the rotating fixture. The welding head mounted on the arm overhead completely welds the outside seams. For welding the girth seams on the inside the tractor welding head is used.

Tractor Type

The Tractor Type Welding Head, illustrated in figure 236, is used for a wide variety of work. This device carries a self propelling mechanism as well as mechanism for feeding the electrode. There is also a guide which enables the welding head to follow a seam automatically without manual guidance.

The operation of the Tractor Type is almost uncanny. Used in conjunction with a rotating fixture such as is described above, this device automatically welds the inside girth seams of large tanks. Its

speed of travel is adjusted to the same rate as the speed of the rotating fixture except that it travels in the opposite direction. The seam passes under the arc and a perfect weld results.

This type of automatic is also used for welding longitudinal seams on large work such as the bottoms and roofs of oil storage tanks. Only lap joints are welded by this machine.

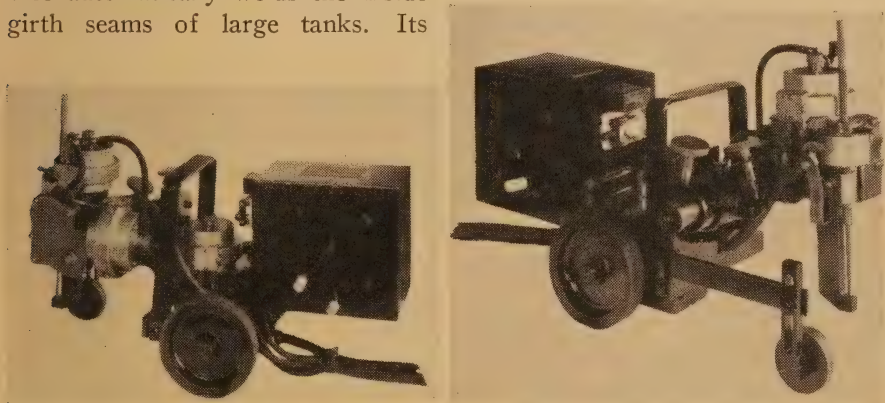


Fig. 236

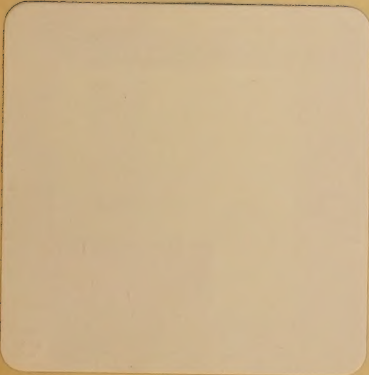
The Tractor Type Welding Head. This welding head is self propelled by a small variable-speed motor. It carries the carbon electrode together with the mechanism for feeding down the electrode as it is consumed. The tractor is used in connection with a rotating fixture, for welding inside girth seams for large tanks. It is also used for welding longitudinal seams on a great variety of work.

Lincoln Engineering Service

The large number of Stable-Arc Welders in operation and the remarkable work which they are doing is a testimonial to the service rendered by Lincoln engineers. Every manufacturer considering re-designing his products to take advantage of the economy of arc welding is urged to submit his problem to the engineering staff of this company. Their experience in re-designing covers a vast range of products. They are prepared to assist manufacturers in re-designing and in working out production problems of all sorts in connection with welding.

INDEX

A		P	
Automatic Welding.....	135	Patterns, Elimination of.....	11
B		R	
Bases	65, 67	Rivet Welds, Strength of.....	113
Boilers, Welded.....	33	Riveted Joints, Efficiency of.....	114
Butt Welds, Strength of.....	111	Riveted Joints, Strength Compared to Welded	115
C		Riveted Joints, Inspection of.....	121
Carbon Arc Welding.....	47	Riveted Joints, Reliability of.....	121
Carbon Electrodes.....	47, 141	Riveting, Cost of.....	35, 123
Cast Iron Compared with Steel.....	5, 23	Rivets, Shearing Value.....	117
Cast Iron, Stiffness of.....	25, 27	Rupturing Force, Linear Inch of Weld..	112, 143
Cast Iron, Safety Factors.....	25	S	
Cast Iron, Strength in Bending.....	29	Safety Factors, Steel and Cast Iron.....	25
Cast Iron, Strength in Compression.....	23	Speed of Welding.....	123
Cast Iron, Strength in Tension.....	27	Stabilizer	151
Cast Iron, Structure of.....	23	Steel Cost Compared with Cast Iron.....	5
Cost of Welding.....	123	Steel Compared to Cast Iron.....	5, 23
D		Steel, Stiffness of.....	25, 27
Designs, Developments of New.....	9	Steel, Strength of.....	5, 23
E		Steel, Strength in Bending.....	5, 25
Equipment for Arc Welding.....	149	Steel, Strength in Compression.....	23
F		Steel, Strength in Tension.....	5, 27
Fillet Welds, Strength of.....	113	Steel, Structure of.....	23
Fixtures, Arc Welded.....	103	Steel Structures	97
G		Strength of Welding.....	111
Gas Welding, Cost of.....	125	T	
J		Tanks, Welded.....	23
Jigs, Arc Welded.....	103	Tool Room, Arc Welding in.....	103
L		W	
Lap Welds, Strength of.....	111	Welded Joints, Inspection of.....	121
Lathe, All Steel.....	75	Welded Joints, Reliability of.....	121
M		Welded Joints, Strength Compared to Riv- eting	115
Maintenance of Arc Welding Equipment....	49	Welded Joints, Tests of.....	119
Maintenance, Application of Arc Weld- ing to.....	107	Welds, Shearing Value.....	117
Metallic Arc Welding.....	47	Welds, Types of.....	51
		Welds, Typical Short Cuts.....	91, 92, 94
		Welding, Automatic	135
		Welding, Automatic Speed and Cost Tables	138
		Welding, Forge or Fire.....	55
		Weldings, Oxy-Acetylene or Gas.....	55
		Welding, Resistance	55
		Welding, Thermit	55
		Wheels	87



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